CLEAN WATER WATER POLLUTION CONTROL RESEARCH SERIES 11024DOC09/71

PB 203 291

W 71-13370-3

Storm Water Management Model

Volume III—User's Manual

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

A

375

STORM WATER MANAGEMENT MODEL

Volume III USER'S MANUAL

by

Metcalf & Eddy, Inc., Palo Alto, California
University of Florida, Gainesville, Florida
Water Resources Engineers, Inc., Walnut Creek, California

for the

Environmental Protection Agency

Contract No. 14-12-501 Project No. 11024EBI
Contract No. 14-12-502 Project No. 11024DOC
Contract No. 14-12-503 Project No. 11024EBJ

September 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.75
Stock Number 5501-0107

WATER POLLUTION CONTROL RESEARCH SERIES

The Water Pollution Control Research Reports describe the results and progress in the control and abatement of pollution of our Nation's waters. They provide a central source of information on the research, development and demonstration activities of the Water Quality Office of the Environmental Protection Agency, through in-house research and grants and contracts with the Federal, State and local agencies, research institutions, and industrial organizations.

Previously issued reports on the Storm and Combined Sewer Pollution Control Program:

11023 FDB 09/70	Chemical Treatment of Combined Sewer Overflows
11024 FKJ 10/70	In-Sewer Fixed Screening of Combined Sewer Overflows
11024 EJC 10/70	Selected Urban Storm Water Abstracts, First Quarterly Issue
11023 --- 12/70	Urban Storm Runoff and Combined Sewer Overflow Pollution
11023 DZF 06/70	Ultrasonic Filtration of Combined Sewer Overflows
11024 EJC 01/71	Selected Urban Runoff Abstracts, Second Quarterly Issue
11020 FAQ 03/71	Dispatching System for Control of Combined Sewer Losses
11022 EFF 12/70	Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems - A Manual of Practice
11022 EFF 01/71	Control of Infiltration and Inflow into Sewer Systems
11022 DPP 10/70	Combined Sewer Temporary Underwater Storage Facility
11024 EQG 03/71	Storm Water Problems and Control in Sanitary Sewers - Oakland and Berkeley, California
11020 FAL 03/71	Evaluation of Storm Standby Tanks - Columbus, Ohio
11024 FJE 04/71	Selected Urban Storm Water Runoff Abstracts, Third Quarterly Issue

To be continued on inside back cover...

EPA REVIEW NOTICE

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The report is a user's manual for

ABSTRACT

A comprehensive mathematical model, capable of representing urban storm water runoff, has been developed to assist administrators and engineers in the planning, evaluation, and management of overflow abatement alternatives.

Hydrographs and pollutographs (time varying quality concentrations or mass values) were generated for real storm events and systems from points of origin in real time sequence to points of disposal (including travel in receiving waters) with user options for intermediate storage and/or treatment facilities. Both combined and separate sewerage systems may be evaluated. Internal cost routines and receiving water quality output assisted in direct cost-benefit analysis of alternate programs of water quality enhancement.( )

Demonstration and verification runs on selected catchments, varying in size from 180 to 5,400 acres, in four U.S. cities (approximately 20 storm events, total) were used to test and debug the model. The amount of pollutants released varied significantly with the real time occurrence, runoff intensity duration, pre-storm history, land use, and maintenance. Storage-treatment combinations offered best cost-effectiveness ratios.

A user's manual and complete program listing were prepared.

This report was submitted in fulfillment of Projects 11024 EBI, DOC, and EBJ under Contracts 14-12-501, 502, and 503 under the sponsorship of the Environmental Protection Agency.

The titles and identifying numbers of the final report volumes are:

Title	EPA Report No.
STORM WATER MANAGEMENT MODEL Volume I - Final Report	11024 DOC 07/71
STORM WATER MANAGEMENT MODEL Volume II - Verification and Testing	11024 DOC 08/71
STORM WATER MANAGEMENT MODEL Volume III - User's Manual	11024 DOC 09/71
STORM WATER MANAGEMENT MODEL Volume IV - Program Listing	11024 DOC 10/71

CONTENTS

Section		Page
1	INTRODUCTION	1
2	EXECUTIVE BLOCK	11
3	RUNOFF BLOCK	33
4	TRANSPORT BLOCK	85
5	STORAGE BLOCK	223
6	RECEIVING WATER BLOCK	291
7	REFERENCES	339
8	GLOSSARY AND ABBREVIATIONS	343
9	APPENDIX	349

FIGURES

Page

INTRODUCTION

1-1 Overview of Model Structure 6

EXECUTIVE BLOCK

2-1 Master Programming Routine 14

2-2 MAIN Program 15

2-3 Data Deck for the Executive Block 22

2-4 Output for Smithville Test Area 31

RUNOFF BLOCK

3-1 Runoff Block 36

3-2 Subroutine RUNOFF 39

3-3 Subroutine HYDRO 40

3-4 Subroutine RHYDRO 42

3-5 Subroutine WSHED 44

3-6 Subroutine GUTTER 46

3-7 Subroutine SFQUAL 48

3-8 Northwood (Baltimore) Drainage Basin "Fine" Plan 50

3-9 Northwood (Baltimore) Drainage Basin "Coarse" Plan 51

3-10 Standard Infiltration-Capacity Curves for Pervious Surfaces 54

3-11 Data Deck for the Runoff Block 58

3-12 Northwood (Baltimore) Gutter/Pipes "Fine" Plan 74

3-13 Typical Output Hyetograph 80

3-14 Typical Output Hydrograph 81

3-15 System Representation of the Example Problem, San Francisco, Selby Street 82

FIGURES (Continued)

Page

TRANSPORT BLOCK

4-1 Transport Block 88

4-2 Subroutine TRANS 91

4-3 Subroutine TSTRDT 96

4-4 Subroutine SLOP 98

4-5 Subroutine FIRST 100

4-6 Typical Drainage Basin in Which Infiltration is to be Estimated 101

4-7 Subroutine INFIL 102

4-8 Components of Infiltration 104

4-9 Prescribed Melting Period 106

4-10 Typical Drainage Basin in Which Dry Weather Flow is to be Estimated 111

4-11 Subroutine FILTH 113

4-12 Determination of Subcatchment and Identification Data to Estimate Sewage at 8 Points 117

4-13 Representative Daily Flow Variation 119

4-14 Representative Hourly Flow Variation 119

4-15 Subroutine DWLOAD 125

4-16 Subroutine INITAL 125

4-17 Subroutine ROUTE 127

4-18 The Intersection of the Straight Line and the Normalized Flow-Area Curve as Determined in ROUTE 130

4-19 Subroutine TSTORG 134

4-20 Subroutine TSROUT 135

4-21 Subroutine TPLUGS 135

4-22 Subroutine QUAL 137

FIGURES (Continued)

		Page
4-23	Sieve Analysis Plot for Sewer Element	139
4-24	Subroutine PRINT	140
4-25	Subroutine TSTCST	140
4-26	Function DEPTH	142
4-27	Function DPSI	142
4-28	Subroutine FINDA	142
4-29	Subroutine NEWTON	144
4-30	Function PSI	144
4-31	Function RADH	145
4-32	Subroutine TINTRP	145
4-33	Function VEL	147
4-34	Data Deck for the Transport Block	148
4-35	Sewer Cross-Sections	153
4-36	Cunnette Section	159
4-37	Example System for I/O Discussion	195
4-38	Schematic of Smithville Test Area	217

STORAGE BLOCK

5-1	Storage Block	226
5-2	Available Treatment Options	228
5-3	Subroutine STORAG	231
5-4	Subroutine TRTDAT	232
5-5	Diagrammatic Sketch of Storage Unit	233
5-6	Subroutine STRDAT	236
5-7	Subroutine TREAT	237
5-8	Subroutine STRAGE	239

FIGURES (Continued)

Page

5-9 Subroutine TRCOST 242

5-10 Inadmissible and Uneconomical Treatment Combinations 243

5-11 Subroutine SROUTE 245

5-12 Subroutine PLUGS 245

5-13 Subroutine INTERP 246

5-14 Data Deck for the Storage Block 248

RECEIVING WATER BLOCK

6-1 Receiving Water Block 295

6-2 Subroutine RECEIV 296

6-3 Subroutine SWFLOW 298

6-4 Subroutine INDATA 299

6-5 Subroutine TIDCF 299

6-6 Subroutine TRIAN 300

6-7 Subroutine PRTOUT 300

6-8 Subroutine SWQUAL 302

6-9 Subroutine INQUAL 303

6-10 Subroutine LOOPQL 305

6-11 Subroutine QPRINT 305

6-12 Data Deck for the Receiving Water Block 306

6-13 Demonstration Estuary 327

TABLES

Page

EXECUTIVE BLOCK

2-1 Summary of Control Words and Action for MAIN Program 21

2-2 Executive Block Card Data 23

2-3 Executive Block Variables 25

2-4 Data Input for Smithville Test Area 29

2-5 Output for Smithville Test Area 30

RUNOFF BLOCK

3-1 Estimate of Manning's Roughness Coefficients 54

3-2 Runoff Block Card Data 59

3-3 Runoff Block Variables 65

3-4 Typical Data Cards 75

3-5 Typical Output, General Information 76

3-6 Typical Subcatchment Output 77

3-7 Typical Gutter/Pipe Output 77

3-8 Computed Arrangement of Subcatchments and Gutter/Pipes 78

3-9 Printed Output of Selected Hydrographs 79

3-10 Computed Rainfall Information 79

3-11 Example Problem Data Input, Surface Quality 83

3-12 Example Problem Output, Surface Quality, General Information 83

3-13 Example Problem Output, Surface Quality, Calculated Volumes 84

TABLES (continued)

Page

TRANSPORT BLOCK

4-1 RINFIL Equations for Three Study Areas 108

4-2 Land Use Classification 116

4-3 Different Element Types Supplied with the Storm Water Management Model 128

4-4 Parameters Required for Non-Conduits 132

4-5 Summary of Area Relationships and Required Conduit Dimensions 155

4-6 Transport Block Card Data 169

4-7 Transport Block Variables 183

4-8 Hypothetical Input Data 196

4-9 Flow-Area Parameters for TRANS Example 199

4-10 Sequence Numbering for TRANS Example 200

4-11 Element Data for TRANS Example 202

4-12 Dry Weather Flow for TRANS Example 203

4-13 Initial Conditions for TRANS Example 204

4-14 Final Conditions for TRANS Example 206

4-15 Inflows for TRANS Example 207

4-16 Outflows for TRANS Example 209

4-17 Land Use Data for Smithville Test Area 218

4-18 Data Deck for Smithville Test Area 220

4-19 Data Output for Smithville Test Area 221

4-20 Data Output for Smithville Test Area 222

TABLES (continued)

Page

STORAGE BLOCK

5-1 Default Values Used in Subroutine TRCOST 241

5-2 Storage Block Card Data 253

5-3 Storage Block Variables 259

5-4 Example 1 - Card Input Data List 273

5-5 Example 1 - Control Information Passed from Transport Block 275

5-6 Example 1 - Output of Subroutine TRTDAT and STRDAT 276

5-7 Example 1 - Output of Performance per Time-Step 278

5-8 Example 1 - Summary of Treatment Effectiveness 279

5-9 Example 1 - Output of Summary of Flows-Max, Ave, Min 280

5-10 Example 1 - Recapitulation of Input/Output Files 281

5-11 Example 1 - Output of Summary of Treatment Costs 282

5-12 Example 2 - Card Input Data List 285

5-13 Example 2 - Output of Subroutine TRTDAT 286

5-14 Example 2 - Output of Performance per Time-Step 287

5-15 Example 2 - Output of Summary of Treatment Effectiveness 288

5-16 Example 2 - Output of Summary of Treatment Costs 289

RECEIVING WATER BLOCK

6-1 Receiving Water Block Card Data 311

6-2 Receiving Water Block Variables 319

6-3 Receiving Water Block Input Data 328

6-4 Sample Quantity Output 330

6-5 Sample Quality Output 336

TABLES (continued)

Page

APPENDIX A

A-1 Average Monthly Degree-Days for Cities in the United States (Base 65F) 351

A-2 Guide for Establishing Water Usage in Commercial Subareas 355

A-3 Guide for Establishing Water Usage in Industrial Subareas 357

SECTION 1

INTRODUCTION

Page

PRESENTATION FORMAT 3

THE COMPREHENSIVE MODEL 4

PROGRAM BLOCKS 7

  Executive Block 7

  Runoff Block 8

  Transport Block 8

  Storage Block 8

  Receiving Water Block 8

SECTION 1

INTRODUCTION

Under the sponsorship of the Environmental Protection Agency a consortium of contractors--Metcalf & Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc.--has developed a comprehensive mathematical model capable of representing urban storm water runoff and combined sewer overflow phenomena. Correctional devices in the form of user selected options for storage and/or treatment are provided with associated estimates of cost. Effectiveness is portrayed by computed treatment efficiencies and modeled changes in receiving water quality.

PRESENTATION FORMAT

The project report is divided into four volumes. This volume, the "User's Manual," contains program descriptions, flow charts, instructions on data preparation and program usage, and test examples.

Volume I, the "Final Report," contains the background, justifications, judgments, and assumptions used in Model development. It further includes descriptions of unsuccessful modeling techniques that were attempted and recommendations for forms of user teams to implement systems analysis techniques most efficiently.

Volume II, "Verification and Testing," describes the methods and results of Model application in four urban catchment areas.

Volume IV, "Program listing," lists the main program, all subroutines, and JCL as used in the demonstration runs.

THE COMPREHENSIVE MODEL

The comprehensive Storm Water Management Model uses a high speed digital computer to simulate real storm events on the basis of rainfall (hyetograph) inputs and system (catchment, conveyance, storage/treatment, and receiving water) characterization to predict outcomes in the form of quantity and quality values.

The simulation technique--that is, the representation of the physical systems identifiable within the Model--was selected because it permits relatively easy interpretation and because it permits the location of remedial devices (such as a storage tank or relief lines) and/or denotes localized problems (such as flooding) at a great number of points in the physical system.

Since the program objectives are particularly directed toward complete time and spatial effects, as opposed to simple maxima (such as the rational formula approach) or only gross effects (such as total pounds of pollutant discharged in a given storm), it is considered essential to work with continuous curves (magnitude versus time), referred to as hydrographs and "pollutographs." The units selected for quality representation, pounds per minute, identify the mass releases as these portray both the volume and the concentration of the release in a single term. Concentrations are also printed out within the program for comparisons with measured data.

An overview of the Model structure is shown in Figure 1-1. In simplest terms the program is built up as follows:

1. The input sources:

   RUNOFF generates surface runoff based on an arbitrary rainfall hyetograph, antecedent conditions, land use, and topography.

   FILTH generates dry weather sanitary flow based on land use, population density, and other factors.

   INFIL generates infiltration into the sewer system based on available groundwater and sewer condition.

2. The central core:

   TRANS carries and combines the inputs through the sewer system in accordance with Manning's equations and continuity; it assumes complete mixing at various inlet points.

   QUAL routes pollutants through transport and models quality changes due to sedimentation or scour.

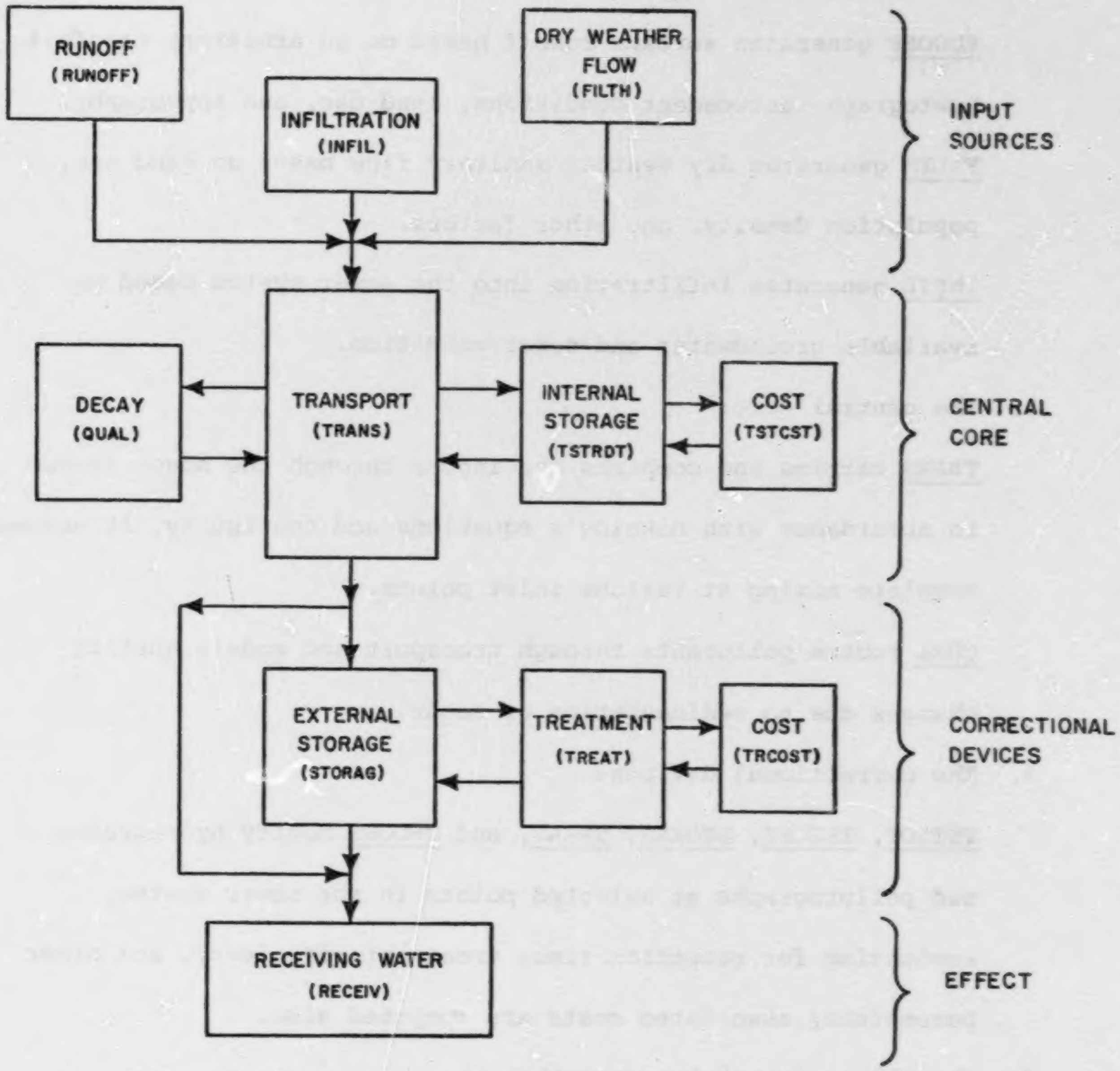
3. The correctional devices:

   TSTRDT, TSTCST, STORAG, TREAT, and TRCOST modify hydrographs and pollutographs at selected points in the sewer system, accounting for retention time, treatment efficiency, and other parameters; associated costs are computed also.

4. The effect (receiving waters):

   RECEIV routes hydrographs and pollutographs through the receiving waters, which may consist of a stream, stream bed; lake or estuary.

The quality constituents considered for simulation are the 5-day BOD,


RUNOFF
(RUNOFF)
INFILTRATION
(INFIL)
DRY WEATHER FLOW
(FILTH)
INPUT SOURCES
DECAY
(QUAL)
TRANSPORT
(TRANS)
INTERNAL STORAGE
(TSTRDT)
COST
(TSTCST)
CENTRAL CORE
EXTERNAL STORAGE
(STORAG)
TREATMENT
(TREAT)
COST
(TRCOST)
CORRECTIONAL DEVICES
RECEIVING WATER
(RECEIV)
EFFECT

Note: Subroutine names are shown in parentheses.

Figure 1-1. OVERVIEW OF MODEL STRUCTURE

total suspended solids, total coliforms (represented as a conservative pollutant), and DO. These constituents were selected on the basis of available supporting data and importance in treatment effectiveness evaluation. Notable omissions, such as floatables, nutrients, and temperature, fell outside the scope of this initial work. Other parameters, such as COD, volatile suspended solids, settleable solids, and fecal coliforms, can be developed by paralleling the structures of their modeled counterparts.

PROGRAM BLOCKS

The adopted programming arrangement, as shown in Figure 2-1, consists of a main control and service block, the Executive Block, and four computational blocks: (1) Runoff Block, (2) Transport Block, (3) Storage Block, and (4) Receiving Water Block.

Executive Block

The Executive Block assigns logical units (disk/tape/drum), determines the block or sequence of blocks to be executed, and, on call, produces graphs of selected results on the line printer. Thus, this Block does no computation as such, while each of the other four blocks are set up to carry through a major step in the quantity and quality computations. All access to the computational blocks and transfers between them must pass through subroutine MAIN of the Executive Block. Transfers are accomplished on offline devices (disk/tape/drum) which may be saved for multiple trials or permanent record.

Runoff Block

The Runoff Block computes the storm water runoff and its characteristics for a given storm for each subcatchment and stores the results in the form of hydrographs and pollutographs at inlets to the main sewer system.

Transport Block

The Transport Block sets up pre-storm conditions by computing DWF and infiltration and distributing them throughout the conveyance system. The block then performs its primary function of flow and quality routing, picking up the runoff results, and producing combined flow hydrographs and pollutographs for the total drainage basin and at selected intermediate points.

Storage Block

The Storage Block uses the output of the Transport Block and modifies the flow and characteristics at a given point or points according to the predefined storage and treatment facilities provided. Costs associated with the construction and operation of the storage/treatment facilities are computed.

Receiving Water Block

The Receiving Water Block accepts the output of the Transport Block directly, or the modified output of the Storage Block, and computes the dispersion and effects of the discharge in the receiving river, lake, or bay.

In principle, the capability exists to run all blocks together in a given computer execution, although from a practical and sometimes necessary (due to computer core limitations) viewpoint, typical runs involve one or two computational blocks together with the Executive Block. Using this approach avoids overlay and, moreover, allows for examination of intermediate results before continuing the computations. Further, it permits the use of intermediate results as start-up data in subsequent execution runs, thereby avoiding the waste of repeating the computations already performed.

This manual expands on these block descriptions by providing for each block:

1. Descriptions of the program subroutines with flow charts.
2. Instructions on data preparation with tables for data card input requirements and an alphabetical list of variables.
3. Examples of the application of procedures described with sample I/O information reproduced.

NOTE: Where maximum quantities (i.e., number of watersheds, number of elements, etc.) are specified, these represent the maximum array areas reserved by the program. These numbers cannot be exceeded without revising the appropriate common, dimension, and related statements. For special runs it may be desirable to reallocate this available array area (e.g., to increase the total number of time-steps above 150).

SECTION 2

EXECUTIVE BLOCK

	Page
BLOCK DESCRIPTION	13
SUBROUTINE DESCRIPTIONS	13
MAIN Program	13
Subroutine GRAPH	16
Subroutine CURVE	17
Subroutine PINE	17
Subroutine PPLOT	18
INSTRUCTIONS FOR DATA PREPARATION	18
Job Control Language (JCL)	18
MAIN Program	19
Subroutine GRAPH	21
EXAMPLE	28

SECTION 2

EXECUTIVE BLOCK

BLOCK DESCRIPTION

The Executive Block performs three functions:

1. Assignment of logical units and files
2. Control of the computational block(s)
3. Graphing of data files by line printer.

The Executive Block consists of a MAIN program and four subroutines that are used to produce graphical output by means of the line printer. The line count for the FORTRAN program is close to 380 lines. No computations as such are performed, except those having to do with scaling variables for graphing. A flow chart of the Executive Block is shown in Figure 2-1.

SUBROUTINE DESCRIPTIONS

MAIN Program

The MAIN program assigns logical units and files, and controls the computational block(s) to be executed. These functions depend on reading in a few data cards which must be supplied according to the needs of a given computer run. In addition, the MAIN program reads certain general data and title information from cards and prints a suitable heading at the beginning of the line-printer output. A flow chart of the MAIN program is shown in Figure 2-2.

Since the various blocks use logical devices for input and output of computations, the MAIN program has provision for assigning logical unit numbers by reading two data cards. The first card may contain up to 20

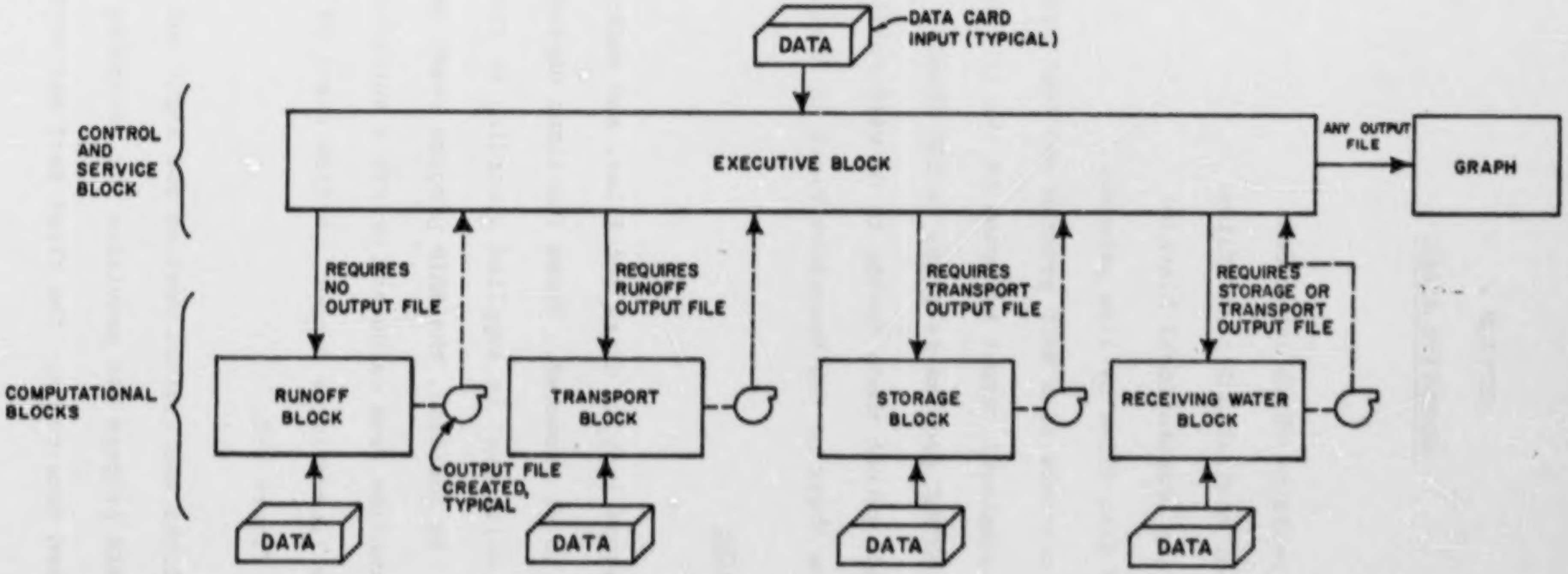
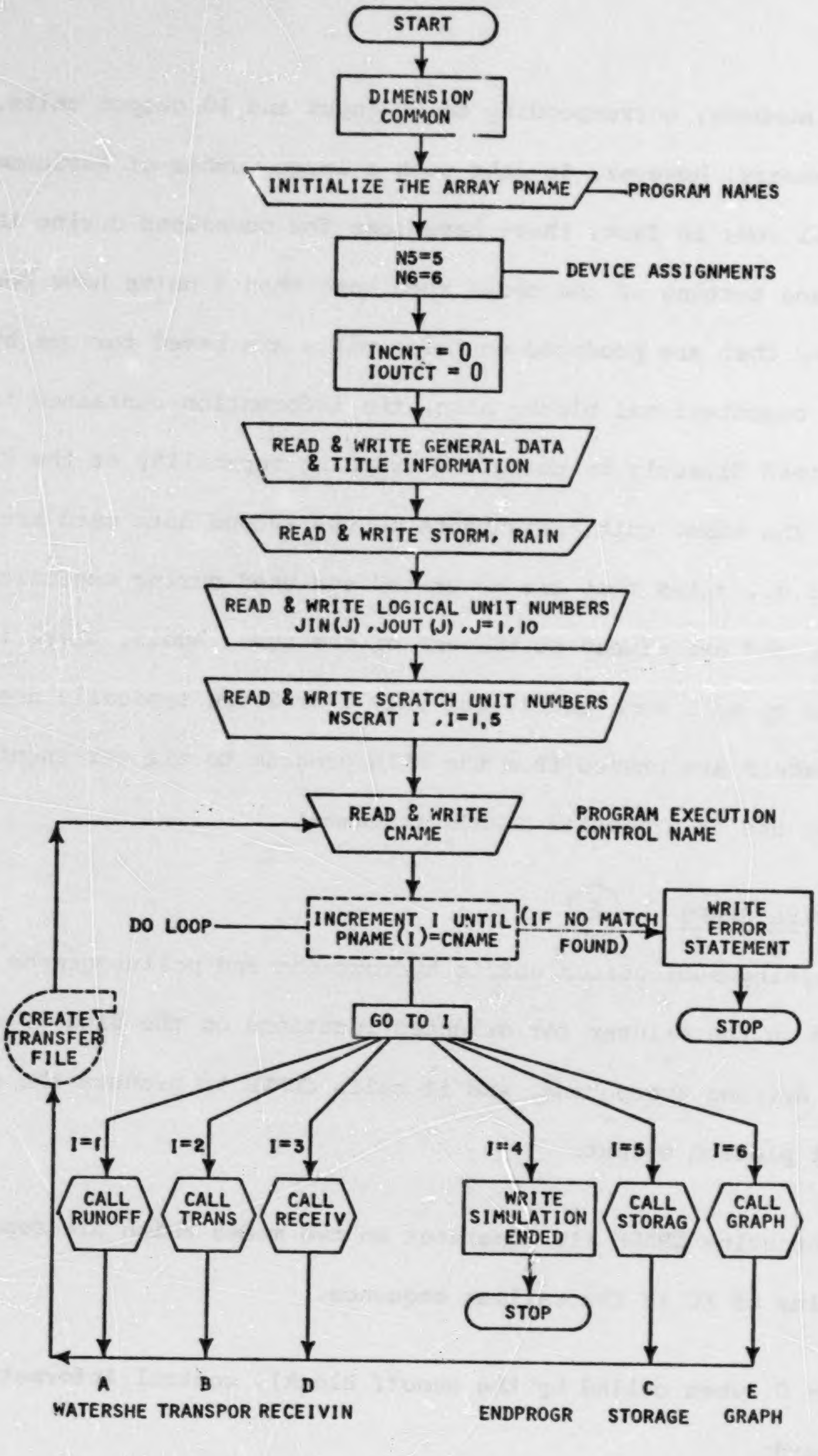

DATA
DATA CARD INPUT (TYPICAL)
CONTROL AND SERVICE BLOCK
EXECUTIVE BLOCK
ANY OUTPUT FILE
GRAPH
REQUIRES NO OUTPUT FILE
REQUIRES RUNOFF OUTPUT FILE
REQUIRES TRANSPORT OUTPUT FILE
REQUIRES STORAGE OR TRANSPORT OUTPUT FILE
COMPUTATIONAL BLOCKS
RUNOFF BLOCK
TRANSPORT BLOCK
STORAGE BLOCK
RECEIVING WATER BLOCK
OUTPUT FILE CREATED, TYPICAL
DATA
DATA
DATA
DATA

Figure 2-1. MASTER PROGRAMMING ROUTINE


START
DIMENSION
COMMON
INITIALIZE THE ARRAY PNAME
PROGRAM NAMES
N5=5
N6=6
DEVICE ASSIGNMENTS
INCNT = 0
IOUTCT = 0
READ & WRITE GENERAL DATA
& TITLE INFORMATION
READ & WRITE STORM, RAIN
READ & WRITE LOGICAL UNIT NUMBERS
JIN(J), JOUT(J), J=1,10
READ & WRITE SCRATCH UNIT NUMBERS
NSCRAT I, I=1,5
READ & WRITE
CNAME
PROGRAM EXECUTION
CONTROL NAME
DO LOOP
INCREMENT I UNTIL
PNAME(I)=CNAME
(IF NO MATCH
FOUND)
WRITE
ERROR
STATEMENT
STOP
CREATE
TRANSFER
FILE
GO TO I
I=1
I=2
I=3
I=4
I=5
I=6
CALL
RUNOFF
CALL
TRANS
CALL
RECEIV
WRITE
SIMULATION
ENDED
STOP
CALL
STORAG
CALL
GRAPH
A
WATERSHE
B
TRANSPOR
D
RECEIVIN
ENDPROGR
C
STORAGE
E
GRAPH

NOTE: A SUBSCRIPT ON CNAME & A SECOND ONE ON PNAME, TAKING VALUES OF ONLY 1 OR 2, ALLOWS NAME TO BE COMPRISED OF 2 PARTS, I.E., TO HAVE FORMAT 2A4.

Figure 2-2. MAIN PROGRAM

integer numbers, corresponding to 10 input and 10 output units. It is not necessary, however, to make such a large number of assignments for the usual run; in fact, there have been few occasions during the development and testing of the model when more than 4 units have been needed. The files that are produced on these units are saved for use by a subsequent computational block; also, the information contained in them can be examined directly by using the graphing capability of the Executive Block. The other unit assignments on the second data card are for scratch files, i.e., files that are generated and used during execution of the program, and are erased at the end of the run. Again, there is provision for up to 5 such units, but only 1 or 2 are typically needed. The unit numbers are passed from the MAIN program to all pertinent subroutines by use of a labeled COMMON statement.

Subroutine GRAPH Ⓔ

The graphing subroutines enable hydrographs and pollutographs to be plotted on the printer for selected locations on the data file. GRAPH is the driving subroutine, and it calls CURVE to produce the actual page of plotted output.

The subroutine GRAPH (IC) operates on two modes which are dependent upon the value of IC in the calling sequence.

If IC = 0 (when called by the Runoff Block), control information is read from cards.

If IC = 1 (when called in the Executive Block), both control information and title information are read from cards.

Subsequently, both options join and the subroutine proceeds as one flow sequence as follows:

1. Information is read from the data file indicating the structure that file.
2. An array ITAB is set up indicating which locations of the data file record are to be plotted.
3. All hydrograph and pollutograph information is read from the data file.
4. For each type of hydrograph and pollutograph, individual curves are selected, transferred into plotting arrays, and outputted in a final plotted form by subroutine CURVE.

Subroutine CURVE

The subroutine CURVE performs the following operations:

1. Determines maximum and minimum of arrays to be plotted.
2. Calculates the range of values and selects appropriate scale intervals.
3. Computes vertical axis labels based upon the calculated scales.
4. Computes horizontal axis labels based upon the calculated scales.
5. Joins individual parts of the curve by subroutine PINE.
6. Outputs final plot.

Subroutine PINE

This subroutine joins two coordinate locations with appropriate characters in the output image array A of PPLOT.

Subroutine PPLOT

This subroutine initializes the plotting array, stores individual locations, and outputs the final image array A for the printer plot.

INSTRUCTIONS FOR DATA PREPARATION

The instructions for data preparation are divided into three parts corresponding to the JCL, the MAIN program usage, and the graphing portion of the Executive Block. Figure 2-3 and Tables 2-2 and 2-3 at the end of these instructions give the procedure for data card preparation and list the variables that are used.

Job Control Language (JCL)

The assignment of logical units requires, in general, the provision for files to be written on specific physical devices. To accomplish this the programmer must supply the necessary JCL. As a rule, JCL is highly machine-dependent; in fact, it often differs on two identical machines at different installations. Therefore, the Storm Water Management Model cannot include JCL that is universally applicable. The following remarks, however, may be useful in gaining insight into what is involved on systems such as an IBM 360/65 or IBM 360/67.

It is convenient on these machines to use the 2314 Disk Storage Devices rather than tape units because of the inherently faster reading and writing speed. At most installations the logical unit corresponding to the card reader is given the number 5 and the line printer is given the number 6. The Storm Water Management Model is programmed on the assumption that units 5 and 6 are so used. Typically, the systems programmers have provided the necessary JCL for these units and also for the card punch. Moreover, JCL may have been provided for scratch units, in which case the unit assignments for scratch files can take advantage of the existing JCL.

Usually, however, the data file and scratch file assignments require JCL to be supplied for each unit. The rules for such JCL must be ascertained from the systems programmers at the installation, since there is considerable variation in unit number availability, etc. In general, one should only set up the units needed in a given run, since there may be a charge for file space that is reserved, even if it is not used.

MAIN Program

The MAIN program controls the computational block(s) to be executed by reading alphameric information on sentinel cards. The array CNAME is read as two alpha words on a single card, each in format of type A4. Thus, for example, CNAME (1) might be WATE and CNAME (2) might be RSHE. When combined, as in printout, the resulting match gives the control word WATERSHE. The program compares this word with a dictionary of such words stored by a DATA statement in the array PNAME. If a match is found, as it would be in this case, control is passed to the appropriate point in the MAIN program to call the initial subroutine of the computational block. Here, for example, a call would be made to the subroutine RUNOFF, which is the initial subroutine for the Runoff Block. After execution of the Runoff Block, which involves calls, in turn, to a number of subsidiary routines, control is eventually returned to the

MAIN program.

The MAIN program again reads a sentinel data card, which might indicate that another block is to be executed. For example, if the Transport Block is to be executed, the control word TRANSPOR would be given, etc. If results are to be graphed, the control word GRAPH would be on the sentinel card, or, if the run is to be terminated, the word ENDPROGR is given on the card. A summary of the control words and corresponding action is given in Table 2-1.

The use of control words on sentinel cards allows considerable flexibility in utilization of the Storm Water Management Model. The most common type of run involves execution of one of the computational blocks along with the graphing of results on the line printer. Thus, for the Runoff Block, such a run would be made by appropriate use of the words RUNOFF, GRAPH, and ENDPROGR. If the entire Model were to be run with graphical output at the end of, say for example, the Transport Block, the sequence would be RUNOFF, TRANSPOR, GRAPH, STORAGE, RECEIVIN, and ENDPROGR. Actually, such a run is prohibitive from the standpoint of machine core storage for most systems, but the program capability is available if such a run is desired.

In order that the program may be used in the way outlined above, dummy subroutines were added to the various blocks so that the program will not terminate because of a "missing" subroutine. This seemed a small price to pay for the convenience and flexibility of the present method.

Table 2-1. SUMMARY OF CONTROL WORDS AND CORRESPONDING ACTION FOR MAIN PROGRAM

Control Word	Action to be Taken
WATERSHE	Execute Runoff Block
TRANSPOR	Execute Transport Block
STORAGE	Execute Storage Block
RECEIVIN	Execute Receiving Water Block
GRAPH	Produce graphs on line printer
ENDPROGR	Terminate run
Any other word	Terminate run

Subroutine GRAPH

The data cards required for subroutine GRAPH are minimal. The first card supplies control information, such as in which tape/disk the hydrographs and pollutographs are stored, the number of curves per graph, and number of pollutants. Element numbers of which plots are to be made are given on the next card. The last three cards supply the titles for the curves, the horizontal axis label, and the vertical axis label. The vertical axis label card is repeated for each pollutant to be plotted and for the hydrograph in the order in which they are to be printed out.

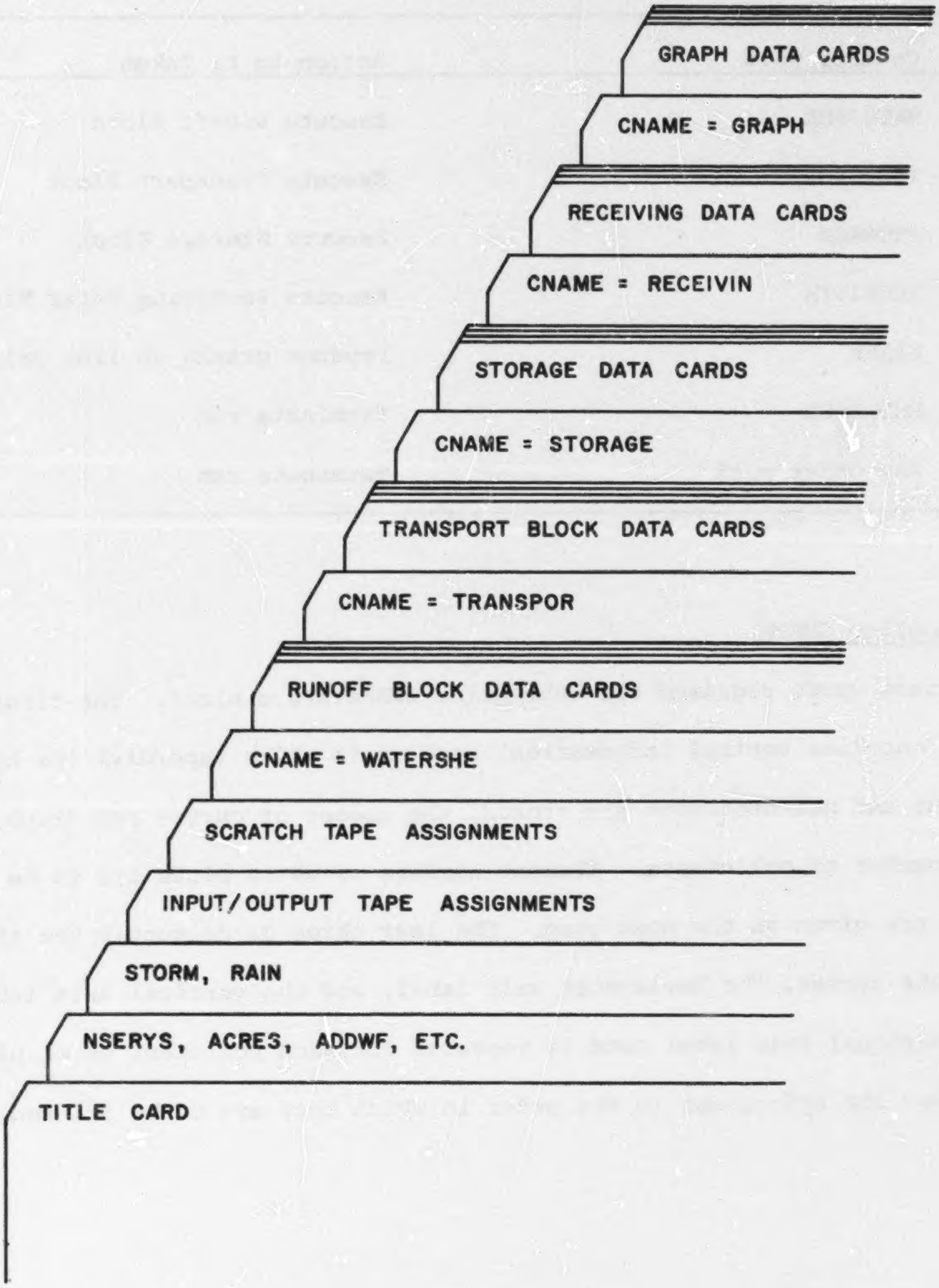

GRAPH DATA CARDS
CNAME = GRAPH
RECEIVING DATA CARDS
CNAME = RECEIVIN
STORAGE DATA CARDS
CNAME = STORAGE
TRANSPORT BLOCK DATA CARDS
CNAME = TRANSPOR
RUNOFF BLOCK DATA CARDS
CNAME = WATERSHE
SCRATCH TAPE ASSIGNMENTS
INPUT/OUTPUT TAPE ASSIGNMENTS
STORM, RAIN
NSERYS, ACRES, ADDWF, ETC.
TITLE CARD

Figure 2-3. DATA DECK FOR THE EXECUTIVE BLOCK

Table 2-2. EXECUTIVE BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	10A4	1-40	Title Card, title of the area being studied.	TITLE1	none
2			General information about the studied area.		
	I5	1-5	Demonstration series number.	NSERYS	none
	F10.1	6-15	Number of acres of the study area.	ACRES	none
	F10.2	16-25	The average daily DWF for the study area.	ADDWF	none
	I5	26-30	Design flow rate frequency, yrs.	NDESYR	none
	F10.1	31-40	Design flow rate (cfs).	DESFLO	none
	I5	41-45	Number of storms being studied.	NSTRMS	none
	F10.1	46-55	Maximum available trunk sewer capacity (cfs).	QTRUNK	none
			REPEAT FOR THE NUMBER OF STORMS.		
3			Storm data cards.		
	4A4	1-16	Date of storm.	STORM	none
	4A4	17-32	Amount of rainfall for this storm.	RAIN	none
4			I/O tape/disk assignments.		
	20I4	1-4	Input tape assignment for first block to be run.	JIN(1)	none
		5-8	Output tape assignment for first block to be run.	JOUT(1)	none
		9-12	Input tape assignment for second block to be run (usually the same as the output tape from first block).	JIN(2)	none
		13-16	Output tape for second block to be run.	JOUT(2)	none
		⋮		⋮	
		77-80	Output tape for tenth block to be run.	JOUT(10)	none
5			Scratch tape/disk assignments.		
	20A4	1-4	First scratch tape assignment.	NSCRAT(1)	none
		5-8	Second scratch tape assignment.	NSCRAT(2)	none
		9-12	Third scratch tape assignment.	NSCRAT(3)	none
		13-16	Fourth scratch tape assignment.	NSCRAT(4)	none
		17-20	Fifth scratch tape assignment.	NSCRAT(5)	none

NOTE: All non-decimal numbers must be right-justified.

Table 2-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			REPEAT CARD 6 FOR EACH BLOCK TO BE CALLED.		
6			Control cards indicating which blocks in the program are to be called.		
	20A4	1-80	Name of block to be called.*	CNAME	none
			= WATERSHED for Runoff Block,		
			= TRANSPORT for Transport Block,		
			= RECEIVING for Receiving Water Block,		
			= STORAGE for Storage Block,		
			= GRAPH for GRAPH subroutines.		
			= ENDPROGRAM for ending the storm water simulation.		
			INSERT THE REMAINING CARDS, IF CARD GROUP 6 INCLUDES CNAME = GRAPH, IMMEDIATELY FOLLOWING EACH GRAPH CARD.		
7			Control card.		
	4I5	1-5	Tape/disk (logical unit) assignment where graph information is stored.	NTAPE	none
		6-10	Number of curves of a graph.	NPCV	5
		11-15	Number of pollutants to be plotted.	NQP	0
		16-20	Number of inlets to be plotted.	NPLOT	All curves on file
			IF NPLOT = 0 (OR BLANK) DELETE THIS CARD.		
8			Inlet selection card.		
	16L5	1-5	First inlet number to be plotted.	IPLOT(1)	none
		6-10	Second inlet number to be plotted.	IPLOT(2)	none
		⋮		⋮	
			Last inlet number to be plotted.	IPLOT(NPLOT)	none
9			Title card.		
	18A4	1-72	Title printed with the plots.	TITL	none
10			Horizontal axis label.		
	20A4	1-80	Horizontal axis label.	HRIZ	none
			REPEAT NQP + 1 TIMES		
11			Vertical axis label.**		
	2A4	1-8	Line 1 of vertical axis label.	VERT(1)	none
		9-16	Line 2 of vertical axis label.	VERT(2)	none
	3A4	17-28	Line 3 of vertical axis label.	VERT(3)	none

---

*Name must start in column 1. GRAPH may be called more than once.

**The first plot to be printed is a flow hydrograph; the second is BOD; the third is SS; and the last is coliform.

Table 2-3. EXECUTIVE BLOCK VARIABLES

Variable Name	C*	Description	Unit
A		The log base 10 of the range of values of y coordinate to be plotted (subroutine CURVE)	
ACRES		Number of acres of study drainage basin	acres
ADDMF		Average DMF	cfs
AXA		X-coordinate of value previously plotted	
AXB		X-coordinate of value to be plotted	
AYA		Y-coordinate of value previously plotted	
AYB		Y-coordinate of value to be plotted	
CURVE		Name of subroutine	
CNAME	C	Computational block name read from data cards	
DESFLO		Design flow rate (of main trunk)	cfs
DUMMY	C	Dummy location to fill data record	
FRANG		Expanded range (even intervals) of y coordinates of curve to be plotted	
GRAPH		Name of subroutine	
HORIZ	C	Horizontal label of curve	
I		The Block selection counter (MAIN)	
IC		Calling sequence control parameter	
ILAB		Output label with plot	
INCNT	C	Array of input logical data file number	
IOUTCT	C	Array of output logical data file number	
IPLOT	C	Array of nodes to be plotted	
ITAB	C	Array indicating which locations of the data file are to be plotted	
IX		Dummy variable	
IXA		Integer value of AXA	
IXB		Integer value of AXB	
IY		Dummy variable	
IYA		Integer value of AYA	
IYB		Integer value of AYB	
J		Subscript counter	
JJ		Subscript counter	
JIN		Array of input disk/tape units	
JOUT	C	Array of output disk/tape units	
K		Subscript counter	
L		Subscript counter	
LX		Transfer location from data file to plot storage	

---

*Variable names shared in common blocks.

Table 2-3 (continued)

Variable Name	C*	Description	Unit
M		Subscript counter	
MC		Do loop counter	
MM		Subscript counter	
N		Subscript counter	
NCP		Number of plots	
NCURVE		Number of curves to be plotted	
NCV		Number of curves/plot	
NDESYR		Frequency of design flow	yr
NLP		Number of types of plot (hydrographs and pollutographs)	
NLOC	C	Node number of hydrograph point	
NPCV		Maximum number of curves/plot	
NN		Subscript counter	
NPLOT		Number of plots	
NPOINT		Number of points on a plot	
NPT		Number of point/curve (array) (CURVE)	
NPT	C	Array containing number of points to be plotted (GRAPH)	
NPTM		Numerical value of NPT	
NQP		Number of quality constituents to be plotted	
NQUAL		Number of quality constituents on data file	

Variable Name	C*	Description	Unit
NR		Subscript counter	
NSCRAT	C	Array of variable scratch units	
NSERYS		Demonstration series number	
NSTEPS		Number of steps in plot	
NSTRMS		Number of storms being studied	
NSYM		Plot number	
NTAPE		Input tape number for plotting	
NVAL		Number of points/data record on a file	
N5		Card input unit number	
N6		Print output unit number	
PINE		Subroutine name	
PNAME		Name used to call the blocks of the Storm Water Model	
PPLOT		Subroutine name	
QTRUNK		Maximum flow rate possible in trunk sewer	cfs
RAIN		Amount of rainfall for a storm	
RANGE		Range of y values to be plotted	
RECEIV		Subroutine name	
RUNOFF		Subroutine name	
STORAG		Subroutine name	
STORM		Date of storm	

Table 2-3 (continued)

Variable Name	C*	Description	Unit
TDELT		Time-step interval	
TIMES		Time-step interval	sec
TITL	C	Title printed out with graphs	
TITLE	C	Title printed out on curves	
TITLE1		Title of drainage basin	
TRANS		Subroutine name	
TZERO		Zero time	sec
VERT	C	Vertical label	
X		X coordinate array (CURVE)	
X	C	X coordinate array (GRAPH)	
XA		X increment used for interpolation	
XINT		Label interval for X	
XMAX		Maximum X value	
XMIN		Minimum X value	
XLAB	C	Numerical scale labels for X	
XO		Start point of line (X coordinate)	
XSCAL		X scale factor	
XT		End point of line (X coordinate)	
X1		Same as XO	
X2		Same as XT	
Y		Y coordinates of curves to be drawn	
Y	C	Y coordinates of curves to be drawn	
YA		Y increment used for interpolation	
YINT		Label interval for Y	
YLAB		Numerical scale labels for Y	
YMAX		Maximum Y value	
YMIN		Minimum Y value	
YO		Start point of line (Y coordinate)	
YSCAL		Y scale factor	
YT		End point of line (Y coordinate)	
YT	C	Hydrograph-pollutograph information on data file	
Y1		Same as YO	
Y2		Same as YT	

EXAMPLE

A hypothetical test area, Smithville, U.S.A., is used to show the data input and portions of the resulting output as required and accomplished by the Executive Block. Table 2-4 is an example of the data deck. The first card is the job title card, the following card supplies general information about the study area used in the title printout, and the third card gives the data and quantity of rainfall for the storm being studied. The next two cards are the tape/disk (file) assignments for transferring information from one program block to another, and the scratch tape/disk assignments, respectively. The first two numbers, zero and eight, refer to the input and output files for the Runoff Block. Since an input file for this Block is not required, the first number is zero.

The output file for Runoff is also the input file for Transport and therefore eight is the first number in the next group of two numbers denoting Transport Block's tape/disk assignments. Nine is the Transport output file. When no other blocks are to be called, the rest of the card is left blank or replaced with zeros. The numbers on the second card refer to the scratch files. A maximum of four are required when using the Transport Block. (Note: all required tape/disk assignments must be properly defined with JCL cards.)

This first group of data cards is used by subroutine MAIN for the logical unit assignment (tape/disk) and title information for the Storm Water Management Model. The succeeding groups of cards are preceded with a control card used by subroutine MAIN. This card transfers control to the appropriate program block. In this example, four such cards exist, WATERSHED, TRANSPORT, GRAPH, and ENDPROGRAM. The data following the first two control cards has been deleted for clarity. The GRAPH card is followed by input data for the plotting of output found on tape/disk nine. ENDPROGRAM needs no succeeding cards.

Partial output from the Executive Block is shown in Table 2-5 and Figure 2-4.

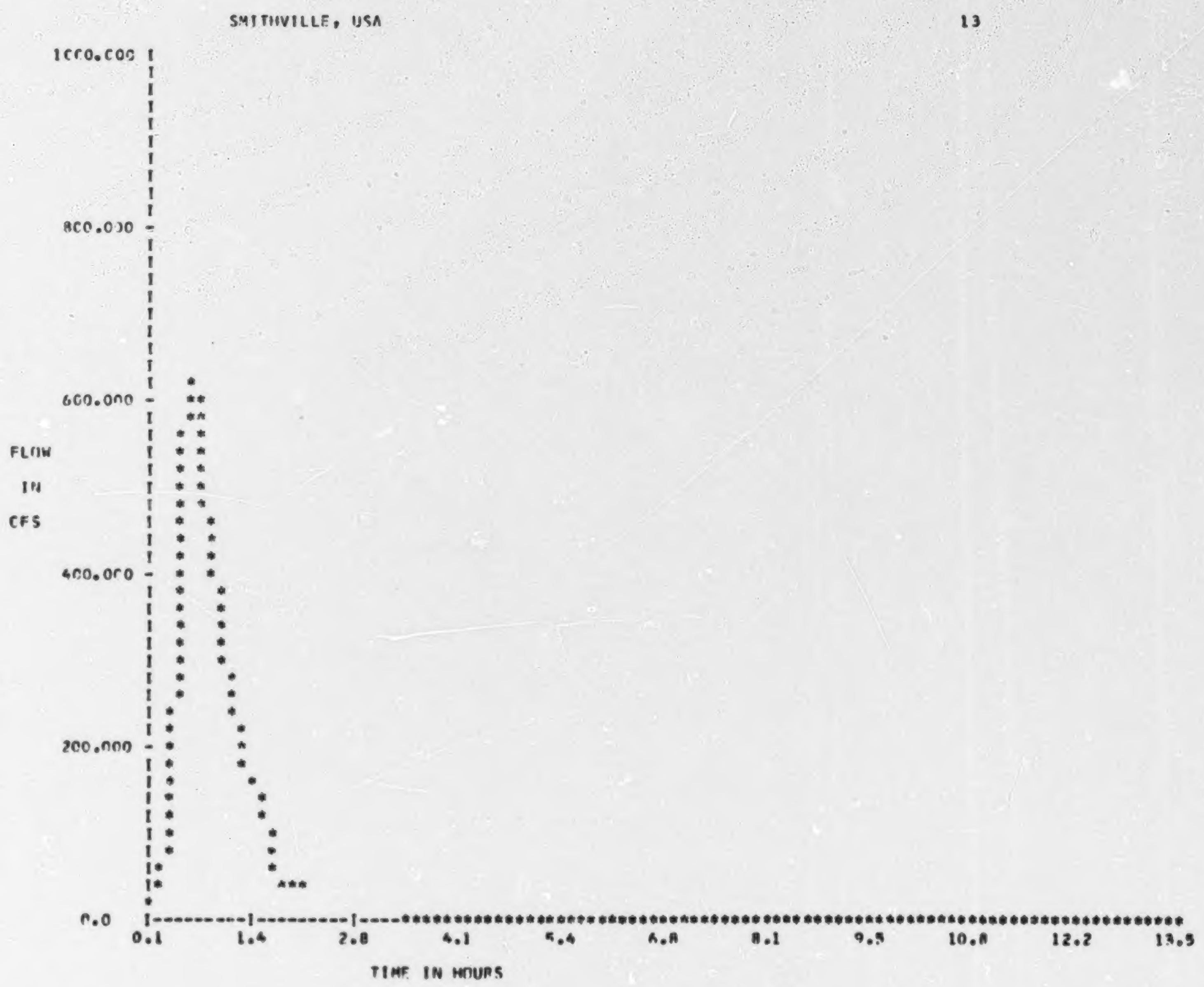
Table 2-4. DATA INPUT FOR SMITHVILLE TEST AREA

```
                                                                  CARD
                                                                  GROUP
                             DATA                                  NO.

SMITHVILLE, USA     PROGRAM CHECK                                   1
    1      500.0      0.00      0       0.0     1       0.0         2
MADE-UP STORM                  1.22                                 3
   0    8    8    9    9    0                                       4
   1    2    3    4   13                                            5
WATERSHED                                                       |
   :                                                            |
TRANSPORT                                                       |   6
   :                                                            |
GRAPH                                                           |
   9     1     3     1                                              7
  13                                                                8
  GRAPH OF THE TRANSPORT OUTPUT TAPE                                9
          TIME IN HOURS                                            10
  FLOW      IN      CFS                                            11
ENDPROGRAM                                                          6
```

Table 2-5. OUTPUT FOR SMITHVILLE TEST AREA

```
              FEDERAL WATER QUALITY ADMINISTRATION          CONTRACTS 14-12-501
              STORMWATER MANAGEMENT PROJECT                           14-12-502
                                                                      14-12-503


              METCALF & EDDY, INC

              WATER RESOURCES ENGINEERS, INC

              UNIVERSITY OF FLORIDA


                  DEMONSTRATION SERIES NO. 1

                  SMITHVILLE, USA    PROGRAM CHECK
                  COMBINED SEWER AREA OF 500.00 ACRES
                  AVERAGE DAILY DRY WEATHER FLOW =     0.0 CFS
                   0-YEAR DESIGN FLOW =       0.0 CFS
                  AVAILABLE MAX. TRUNK CAPACITY =      0.0 CFS

                  STORMS STUDIED:           TOTAL RAINFALL, INCHES
                 MADE-UP STORM                               1.22


TAPE ASSIGNMENTS
    0      8      9      0      0      0      0      0      0      0
    8      9      0      0      0      0      0      0      0      0

TAPE ASSIGNMENTS
    1      2      3      4     13
```

Figure 2-4. OUTPUT FOR SMITHVILLE TEST AREA



SECTION 3

RUNOFF BLOCK

	Page
BLOCK DESCRIPTION	35
Surface Flows	35
Surface Quality	37
SUBROUTINE DESCRIPTIONS	38
Subroutine RUNOFF	38
Subroutine HYDRO	38
Subroutine RHYDRO	41
Subroutine WSHED	43
Subroutine GUTTER	45
Subroutine GRAPH	45
Subroutine SFQUAL	47
INSTRUCTIONS FOR DATA PREPARATION	49
Surface Flows	49
Step 1 - Method of Discretization	49
Step 2 - Estimate of Coefficients	53
Step 3 - Data Card Preparation	53
Surface Quality	56
EXAMPLES	72
Example 1 - Surface Flows	72
Example 2 - Surface Quality	72

SECTION 3

RUNOFF BLOCK

BLOCK DESCRIPTION

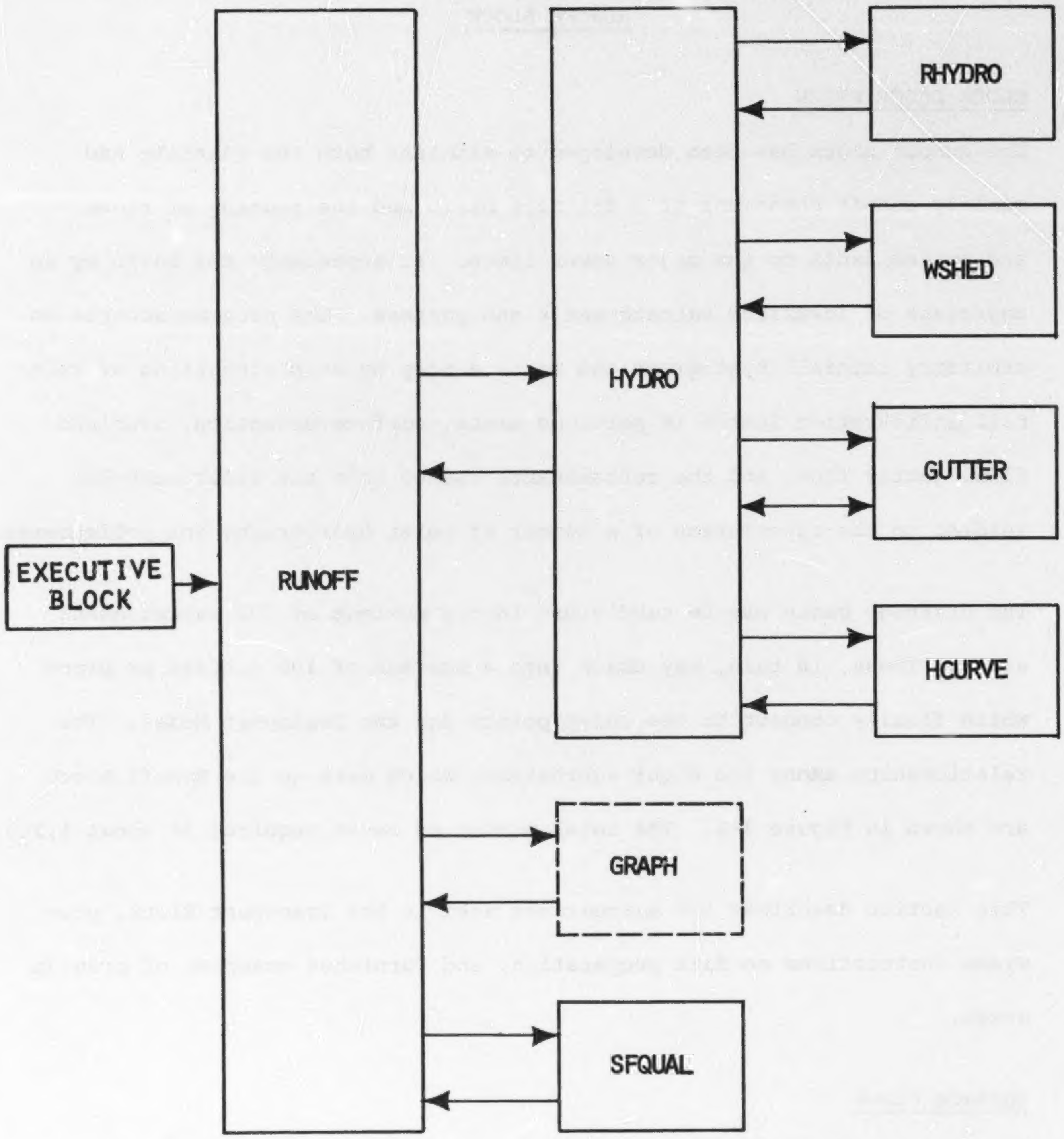
The Runoff Block has been developed to simulate both the quantity and quality runoff phenomena of a drainage basin and the routing of flows and contaminants to the major sewer lines. It represents the basin by an aggregate of idealized subcatchments and gutters. The program accepts an arbitrary rainfall hyetograph and makes a step by step accounting of rainfall infiltration losses in pervious areas, surface detention, overland flow, gutter flow, and the contaminants washed into the inlet manholes leading to the calculation of a number of inlet hydrographs and pollutographs.

The drainage basin may be subdivided into a maximum of 100 subcatchment areas. These, in turn, may drain into a maximum of 100 gutters or pipes which finally connect to the inlet points for the Transport Model. The relationships among the eight subroutines which make up the Runoff Block are shown in Figure 3-1. The total number of cards required is about 1,300.

This section describes the subroutines used in the Transport Block, provides instructions on data preparation, and furnishes examples of program usage.

Surface Flows

The core of the Runoff Model is the routing of hydrographs through the system. This is accomplished by a combination of overland flow and pipe routing.


RHYDRO
WSHED
HYDRO
GUTTER
EXECUTIVE BLOCK
RUNOFF
HCURVE
GRAPH
SFQUAL

Note: **Subroutine GRAPH is a part of the Executive Block but is shown here since it is called directly by RUNOFF.**

Figure 3-1. RUNOFF BLOCK

Three types of elements are available to the user:

1. Subcatchment elements (overland flow)
2. Gutter elements (channel flow)
3. Pipe elements (special case of channel flow).

Flow from subcatchment elements is always into gutter/pipe elements, or inlet manholes. The subcatchment elements receive rainfall, account for infiltration loss using Horton's equation, and permit surface storage such as ponding or retention on grass or shrubbery. If gutter/pipe elements are used, these route the hydrographs from the watershed elements to the entry to the main sewer system. Pipes are permitted to surcharge when full.

Surface Quality

The quality of the inlet flows is determined separately (subroutine SFQUAL) from the inlet hydrographs. The quantity of pollutants washed off the land surface of the drainage basin is added directly to the inlet manholes. Initially the program calculates the amount of contaminants allowed to accumulate on the ground prior to the storm, and then, taking into account rainfall intensity, major land use, and land slope, the washed off pollutants are added to the inlet manholes resulting in pollutographs.

Output from the program consists of hydrographs and pollutographs on disk/tape for use in the Transport Block and printed and/or plotted information for the user.

Three types of elements are available to the user:

1. Subcatchment elements (overland flow)
2. Gutter elements (channel flow)
3. Pipe elements (special case of channel flow).

Flow from subcatchment elements is always into gutter/pipe elements, or inlet manholes. The subcatchment elements receive rainfall, account for infiltration loss using Horton's equation, and permit surface storage such as ponding or retention on grass or shrubbery. If gutter/pipe elements are used, these route the hydrographs from the watershed elements to the entry to the main sewer system. Pipes are permitted to surcharge when full.

Surface Quality

The quality of the inlet flows is determined separately (subroutine SFQUAL) from the inlet hydrographs. The quantity of pollutants washed off the land surface of the drainage basin is added directly to the inlet manholes. Initially the program calculates the amount of contaminants allowed to accumulate on the ground prior to the storm, and then, taking into account rainfall intensity, major land use, and land slope, the washed off pollutants are added to the inlet manholes resulting in pollutographs.

Output from the program consists of hydrographs and pollutographs on disk/tape for use in the Transport Block and printed and/or plotted information for the user.

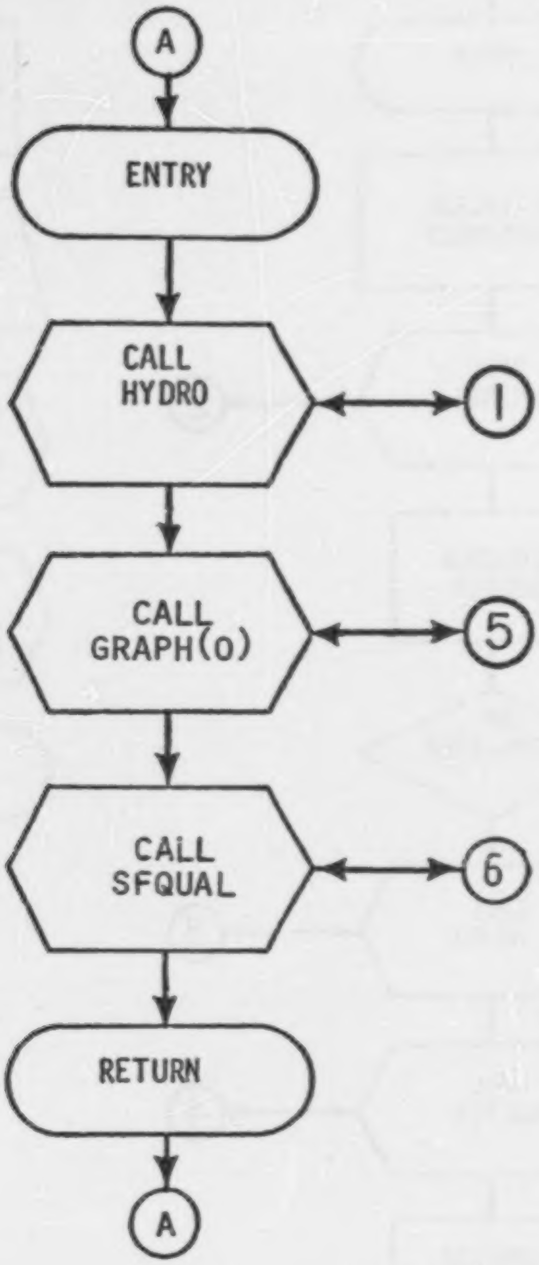

A
ENTRY
CALL HYDRO
1
CALL GRAPH(O)
5
CALL SFQUAL
6
RETURN
A

Figure 3-2. SUBROUTINE RUNOFF

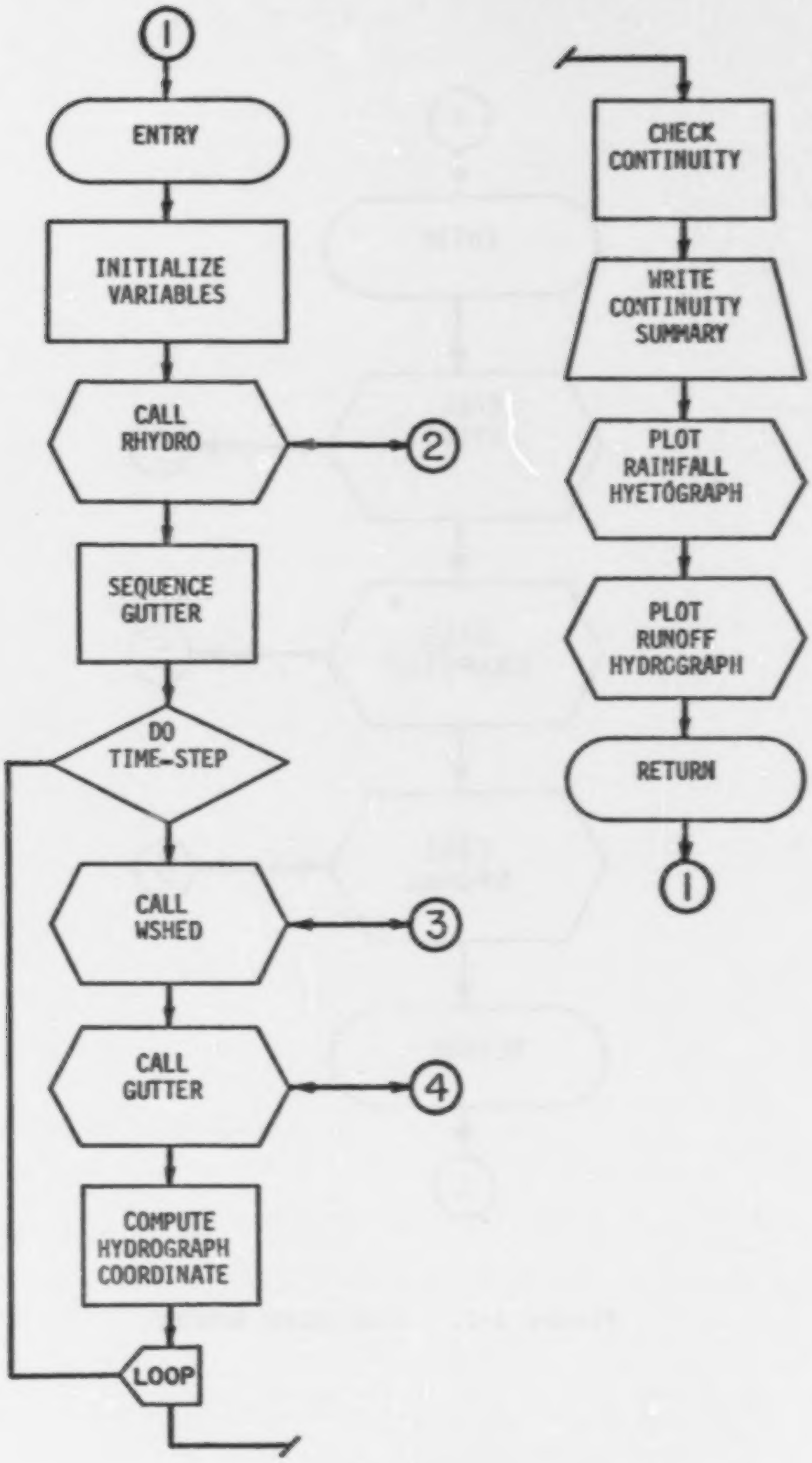

1
ENTRY
INITIALIZE VARIABLES
CALL RHYDRO
2
SEQUENCE GUTTER
DO TIME-STEP
CALL WSHED
3
CALL GUTTER
4
COMPUTE HYDROGRAPH COORDINATE
LOOP
CHECK CONTINUITY
WRITE CONTINUITY SUMMARY
PLOT RAINFALL HYETOGRAPH
PLOT RUNOFF HYDROGRAPH
RETURN
1

Figure 3-3. SUBROUTINE HYDRO

Finally, the rainfall hyetograph and the inlet hydrograph are plotted as an output. The control is then returned to subroutine RUNOFF.

Subroutine RHYDRO ②

This subroutine is called by HYDRO to read input data related to the subcatchment areas and to perform some initial preparatory work, such as unit conversion and error detection. A normal execution of RHYDRO should provide all the necessary information for the calculation of a runoff hydrograph. Figure 3-4 shows the flow chart for subroutine RHYDRO.

There are four basic categories of input data. The general information includes a number representing the subcatchment area, period of simulation, and a key indicating if the rainfall hyetograph is spatially different from that of the previous basin. A new rainfall hyetograph will be read if it is so indicated. Otherwise, that part of the read operation will be skipped and the rainfall of the previous inlet drainage basin will be used. The first basin must have a rainfall input.

The program proceeds to read subcatchment data, e.g., the size, width, ground slope. The gutter information is read soon afterward.

It must be noted that the program can detect only logical errors such as indexing numbers. However, the input data are tabulated by the computer to check against the original for absolute correctness.

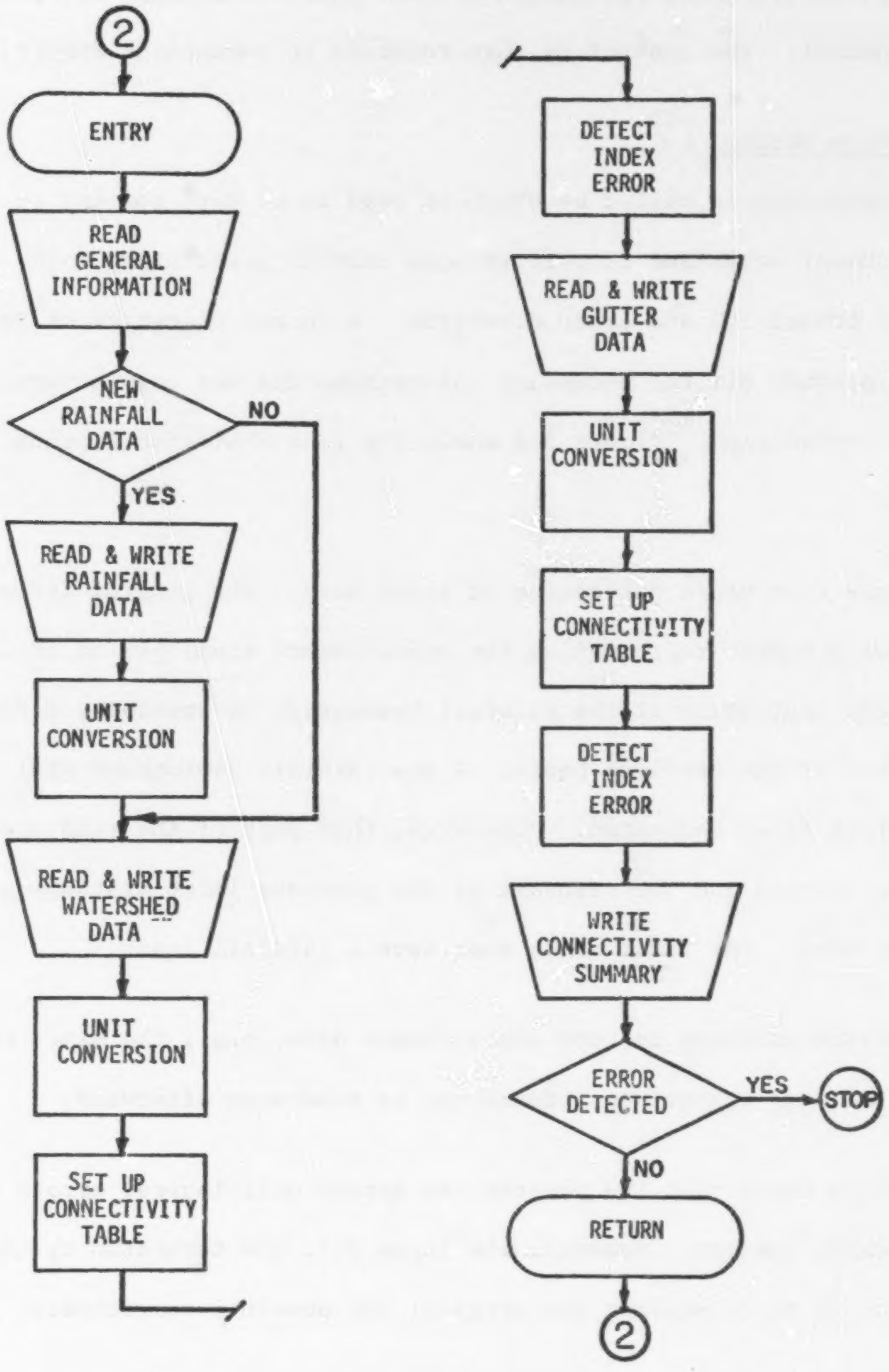

2
ENTRY
READ GENERAL INFORMATION
NEW RAINFALL DATA
NO
YES
READ & WRITE RAINFALL DATA
UNIT CONVERSION
READ & WRITE WATERSHED DATA
UNIT CONVERSION
SET UP CONNECTIVITY TABLE
DETECT INDEX ERROR
READ & WRITE GUTTER DATA
UNIT CONVERSION
SET UP CONNECTIVITY TABLE
DETECT INDEX ERROR
WRITE CONNECTIVITY SUMMARY
ERROR DETECTED
YES
STOP
NO
RETURN
2

Figure 3-4. SUBROUTINE RHYDRO

Subroutine WSHED ③

This subroutine computes the depth and flow rate of water overland. The logic of subroutine WSHED can be seen in Figure 3-5. As shown in Figure 3-3, the subroutine is called by HYDRO at each incremental period of integration. During that period, the rainfall intensity is first interpolated from the designated rainfall hyetograph for each subcatchment. This rainfall intensity is assumed uniform over each subcatchment.

A DO loop is set up to treat the subcatchments, one at a time. For a subcatchment, the amount of infiltration loss is calculated using Horton's equation,

$$\text{Infiltration loss} = f_o + (f_i - f_o)\, e^{-\alpha t} \tag{1}$$

where f_o , f_i and α are coefficients and t is the time from the start of rainfall. The loss is compared with the amount of water existing on the subcatchment plus the rainfall. If the loss is larger, it is set equal to the amount available and the remainder of the computation is skipped.

The water depth will thus increase without inducing an outflow until it reaches the specified detention requirement. Beyond that, the outflow rate is calculated by Manning's equation using depth as the hydraulic radius. An iterative procedure termed Newton-Raphson's technique is established to determine the water depth and the outflow rate so that the continuity of water mass is satisfied.

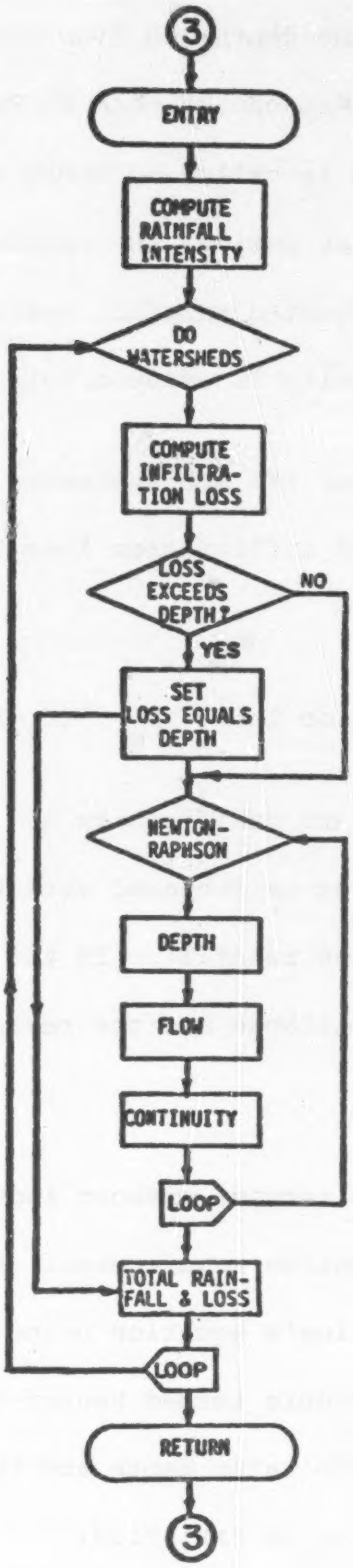

3
ENTRY
COMPUTE RAINFALL INTENSITY
DO WATERSHEDS
COMPUTE INFILTRATION LOSS
LOSS EXCEEDS DEPTH?
NO
YES
SET LOSS EQUALS DEPTH
NEWTON-RAPHSON
DEPTH
FLOW
CONTINUITY
LOOP
TOTAL RAINFALL & LOSS
LOOP
RETURN
3

Figure 3-5. SUBROUTINE WSHED

Upon completion, the subroutine will return with a set of water depths on each subcatchment for the next time-step. It also produces the flow necessary for subsequent routing in the gutters.

Subroutine GUTTER ④

The function of subroutine GUTTER is very similar to that of WSHED and is shown in Figure 3-6. It calculates a complete set of water depth and flow for gutters and pipes.

The computation also proceeds one gutter at a time. For a gutter, the inflow from tributary subcatchments and gutters is first computed. The Newton-Raphson's iterative procedure is again used to determine the depth and outflow of gutters so that the mass (volume) of water is conserved. The flow is computed by Manning's equation. The hydraulic radius of trapezoidal gutters and circular pipes is calculated separately in different paths of the program.

A pipe may surcharge when it is full and the inflow is larger than the outflow capacity. In this case, the surcharged amount will be computed and stored at the head end of the pipe. A message will be printed to indicate the time, location, and total amount of the surcharge. The pipe will remain full until the stored water is completely drained.

Subroutine GRAPH ⑤

This subroutine, a part of the Executive Block, is called directly by the RUNOFF subroutine. For further description see Section 2.

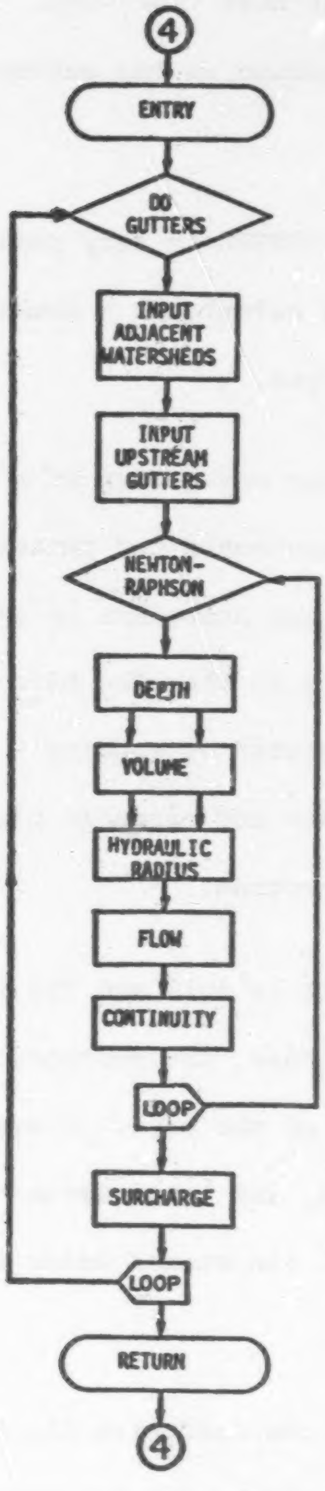

4
ENTRY
DO GUTTERS
INPUT ADJACENT WATERSHEDS
INPUT UPSTREAM GUTTERS
NEWTON-RAPHSON
DEPTH
VOLUME
HYDRAULIC RADIUS
FLOW
CONTINUITY
LOOP
SURCHARGE
LOOP
RETURN
4

Figure 3-6. SUBROUTINE GUTTER

Subroutine SFQUAL ⑥

The surface quality program simulates the removal of pollutants from the ground surface and from catchbasins by storm water runoff. This program is driven by the RUNOFF subroutine. It is called after HYDRO completes its task of computing runoff hydrographs for each inlet.

This subroutine has the capability of computing the BOD, suspended solids, and coliforms carried by the runoff for 50 inlets. Each inlet can have as many as five separate subareas contributing to it, each one having a different type of land use.

A flow chart of the program is shown in Figure 3-7. The general information for computation instructions is read first, e.g., number of subareas, inlets, time-steps. Data which are general for the total system are read next. General computations are made including initializing all variables.

The next step in the program is to read specific subarea information so that the quantities of pollutants on their surface prior to the start of the storm are set. The runoff values obtained from HYDRO are read for every inlet in each time-step. Pollutant removals for each subarea are computed. The removals in each subarea during each time-step are added for the subareas having a common inlet point.

Pollutants removed by the runoff for each inlet area are written for each time-step. Total pollutant quantities removed from each inlet area

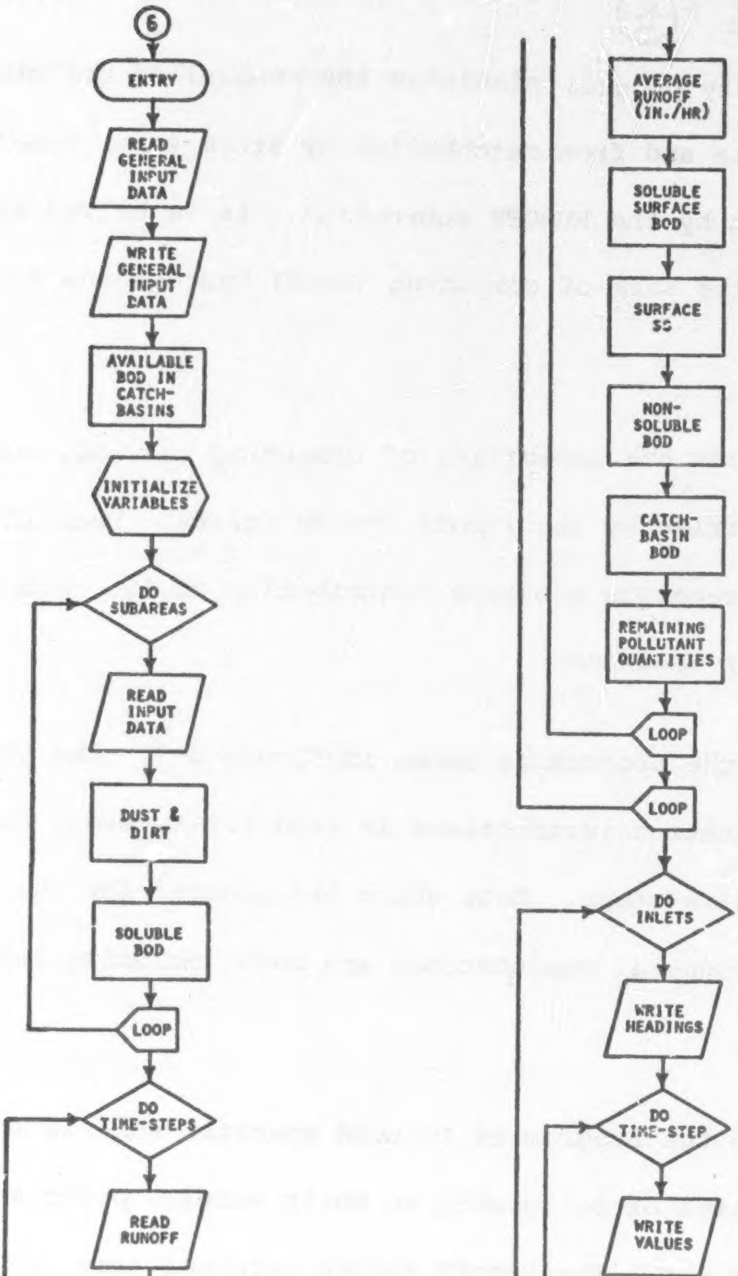

6
ENTRY
READ GENERAL INPUT DATA
WRITE GENERAL INPUT DATA
AVAILABLE BOD IN CATCH-BASINS
INITIALIZE VARIABLES
DO SUBAREAS
READ INPUT DATA
DUST & DIRT
SOLUBLE BOD
LOOP
DO TIME-STEPS
READ RUNOFF
DO INLETS
AVERAGE RUNOFF (CFS)
LOOP
DO SUBAREAS
AVERAGE RUNOFF (IN./HR)
SOLUBLE SURFACE BOD
SURFACE SS
NON-SOLUBLE BOD
CATCH-BASIN BOD
REMAINING POLLUTANT QUANTITIES
LOOP
LOOP
DO INLETS
WRITE HEADINGS
DO TIME-STEP
WRITE VALUES
CLOCK TIME
LOOP
LOOP
RETURN
6

Figure 3-7. SUBROUTINE SFQUAL

are also written. Pollutant quantities on the surface prior to the start of runoff are written so that a comparison may be made between pollutant quantities available and those removed.

INSTRUCTIONS FOR DATA PREPARATION

Instructions on the use of the Runoff Block are divided into two sections, surface flows and surface quality.

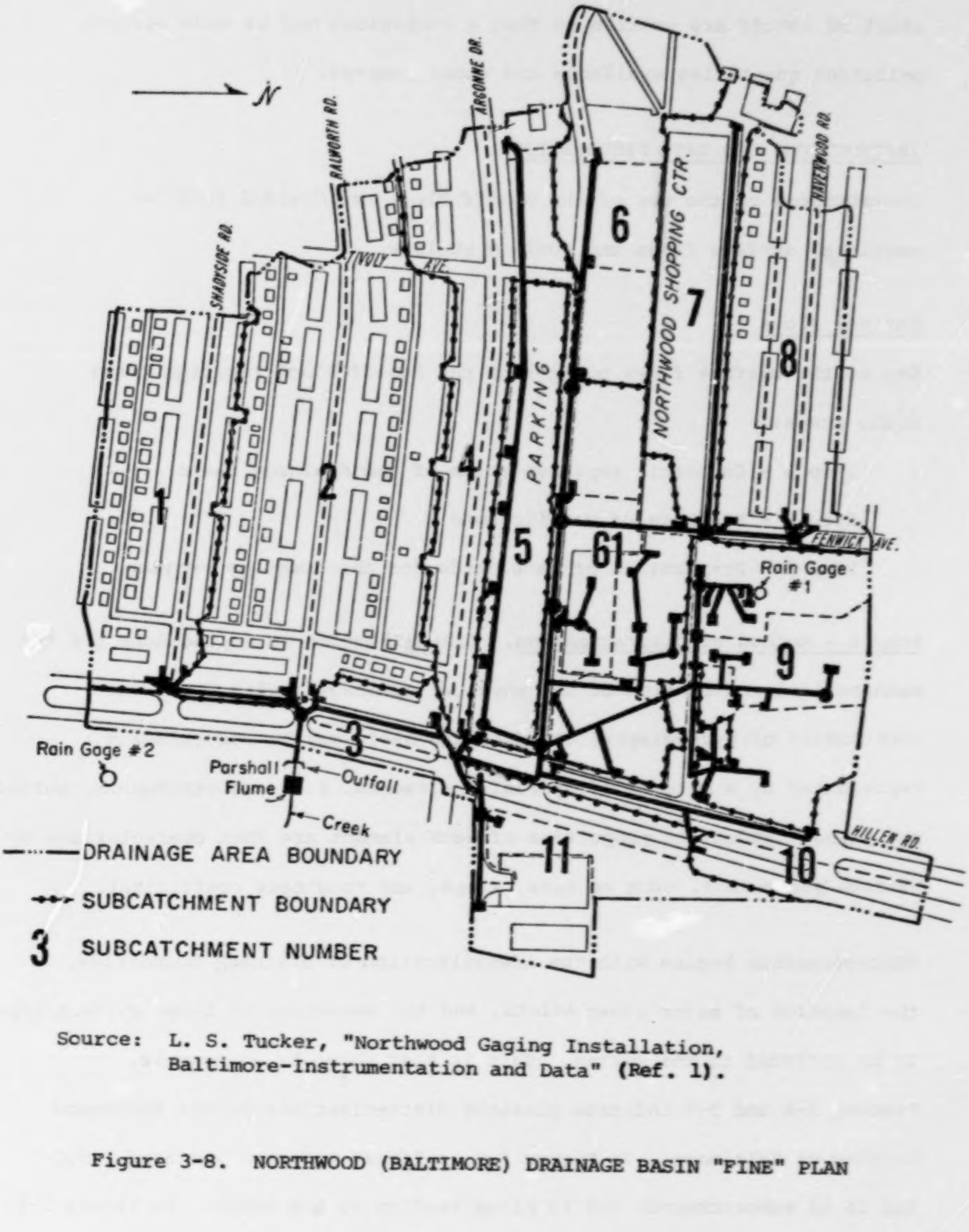
Surface Flows

Use of the surface flows portion of the Runoff Block requires three basic steps:

Step 1 - Geometric representation of the drainage basin
Step 2 - Estimate of coefficients
Step 3 - Preparation of data cards for the computer program.

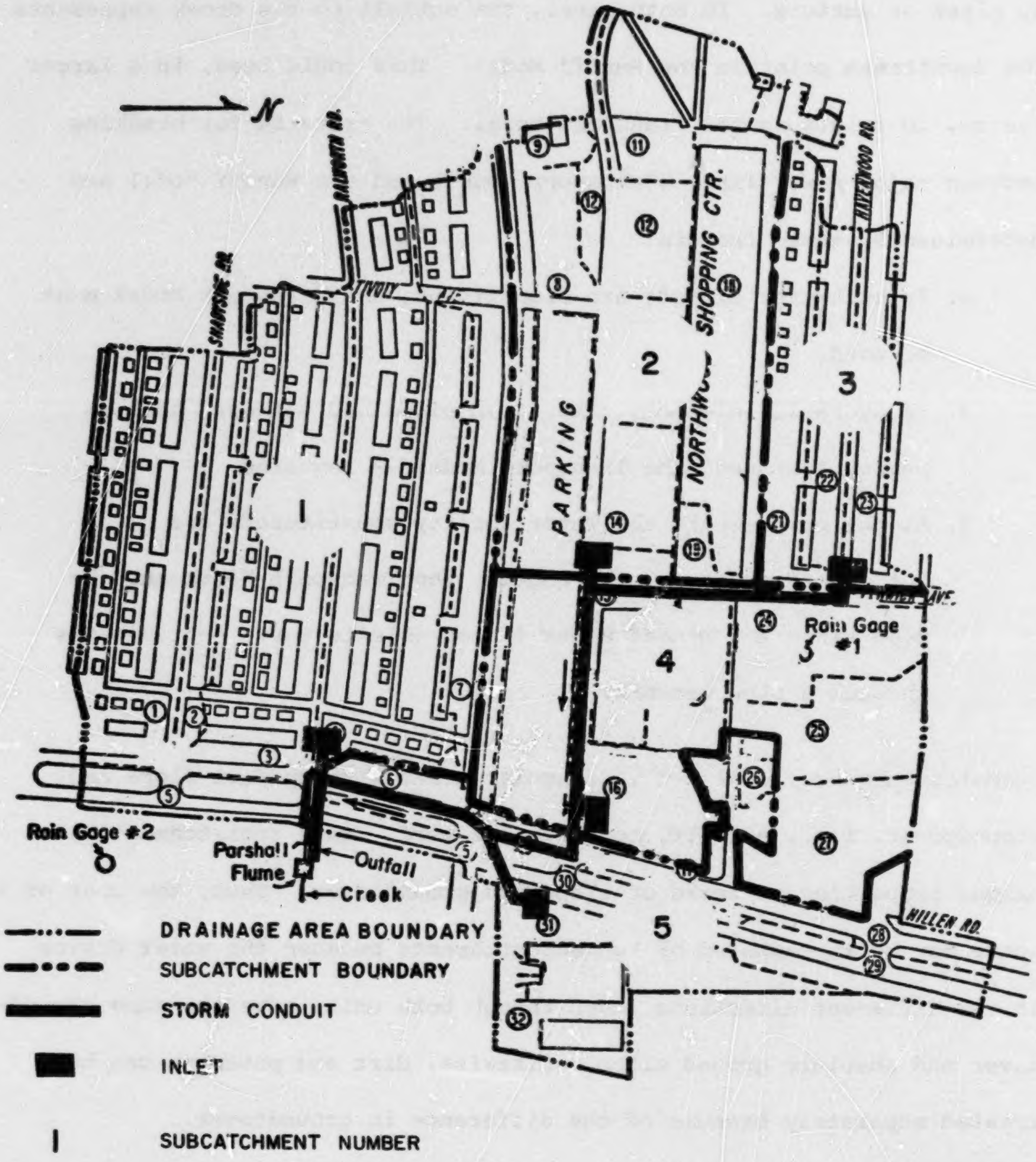
Step 1 - Method of Discretization. Discretization is a procedure for the mathematical abstraction of the physical drainage system. For the computation of hydrographs, the drainage basin may be conceptually represented by a network of hydraulic elements, i.e., subcatchments, gutters, and pipes. Hydraulic properties of each element are then characterized by various parameters, such as size, slope, and roughness coefficient.

Discretization begins with the identification of drainage boundaries, the location of major sewer inlets, and the selection of those gutters/pipes to be included in the system. This is best shown by an example. Figures 3-8 and 3-9 indicate possible discretizations of the Northwood section of Baltimore. In Figure 3-8, a "fine" approach was used resulting in 12 subcatchments and 13 pipes leading to the inlet. In Figure 3-9,


N
SHADYSIDE RD.
RAILWORTH RD.
TIVOLY AVE.
ARGONNE DR.
NORTHWOOD SHOPPING CTR.
HAVENWOOD RD.
PARKING
FENWICK AVE.
HILLEN RD.
1
2
3
4
5
6
61
7
8
9
10
11
Rain Gage #1
Rain Gage #2
Parshall Flume
Outfall
Creek
DRAINAGE AREA BOUNDARY
SUBCATCHMENT BOUNDARY
3 SUBCATCHMENT NUMBER

Source: L. S. Tucker, "Northwood Gaging Installation, Baltimore-Instrumentation and Data" (Ref. 1).

Figure 3-8. NORTHWOOD (BALTIMORE) DRAINAGE BASIN "FINE" PLAN


N
BALDWIN RD.
SHADYSIDE RD.
TIVOLI AVE.
PARKING
NORTHWOOD SHOPPING CTR.
HAVENWOOD RD.
HILLEN RD.
1
2
3
4
5
Rain Gage #1
Rain Gage #2
Parshall Flume
Outfall
Creek
DRAINAGE AREA BOUNDARY
SUBCATCHMENT BOUNDARY
STORM CONDUIT
INLET
SUBCATCHMENT NUMBER

Source: L. S. Tucker, "Northwood Gaging Installation, Baltimore-Instrumentation and Data," (Ref. 1).

Figure 3-9. NORTHWOOD (BALTIMORE) DRAINAGE BASIN "COARSE" PLAN

a "coarse" discretization was used resulting in 5 subcatchment areas and no pipes or gutters. In both cases, the outfall to the creek represents the downstream point in the Runoff Model. This could lead, in a larger system, to inlets in the Transport Model. The criteria for breaking between major sewer lines (Transport Model) and the Runoff Model are determined by three factors:

1. If backwater effects are significant, the Transport Model must be used.
2. If hydraulic elements other than pipes and gutters, such as pumps, are used, the Transport Model is required.
3. At the point where the water quality constituents are introduced and are to be routed, the Transport Block must be used since the Runoff Block is not able to route contaminates through a pipe network.

Subcatchments are idealized rectangular areas with uniform slope and groundcover, i.e., asphalt, concrete, or turf. Each subcatchment has unique properties in terms of slope and groundcover. Thus, the roof of a house may be represented by two subcatchments because the water drains in two different directions, even though both units have the same groundcover and absolute ground slope. Likewise, dirt and pavement can be treated separately because of the difference in groundcover.

While the subdivision described can be taken to infinitesimal detail in theory, computation time and manpower requirements become prohibitive in practice. No ready rule for the subdivision can be offered, but a minimum of five subcatchments per drainage basin is recommended. This permits flow routing (time offset) between hydrographs.

Step 2 - Estimate of Coefficients. Coefficients and parameters necessary to characterize the hydraulic properties of a subcatchment include surface area, width, ground slope, roughness coefficient, detention depth, infiltration rate, and percent imperviousness. Since real subcatchments are not rectangular areas experiencing uniform overland flow, average values must be selected for computation purposes.

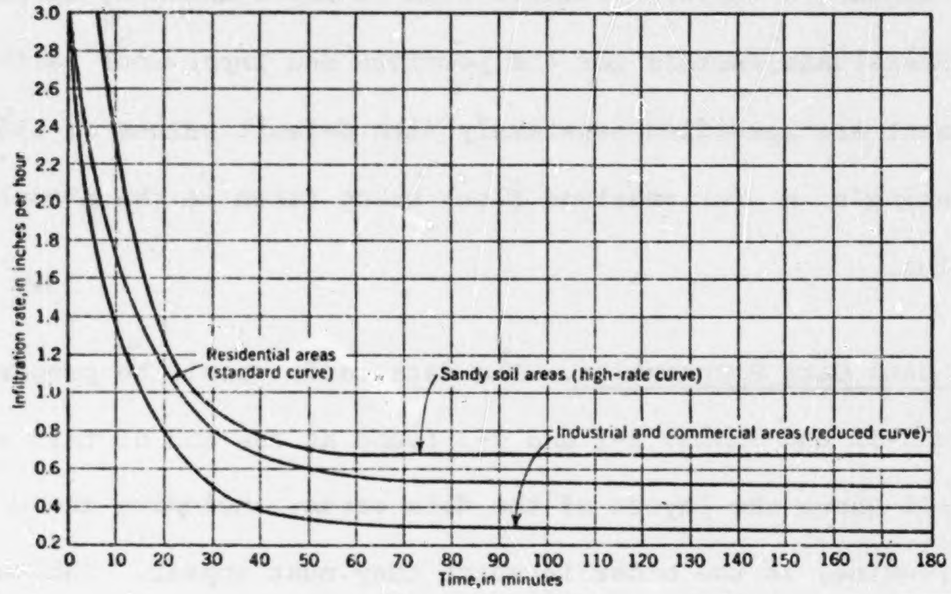
For the roughness coefficient, one can use the values given in Table 3-1, as suggested by Crawford and Linsley (Ref. 2). Detention depths are taken by the program as 1/16th-inch for impervious areas and 1/4-inch for pervious areas, unless specified at other values by the user. The infiltration rate can be estimated from "standard infiltration capacity curves" shown in Figure 3-10, which was produced by the American Society of Civil Engineers (ASCE). Infiltration is important only in pervious areas. Resistance factors for the pervious and impervious parts of a subcatchment are specified separately with default values of .250 and .013 (Manning's n for overland flow) being taken in the absence of other information.

Step 3 - Data Card Preparation. The data cards should be prepared according to Figure 3-11 and Tables 3-2 and 3-3 found at the end of this subsection. Figure 3-11 shows the layout of the data cards, including those for the quality routine, in the order in which they must appear. Tables 3-2 and 3-3, respectively, show how the data cards are to be punched and list the description of variables used in this program Block.

Table 3-1. ESTIMATE OF MANNING'S ROUGHNESS COEFFICIENTS

Ground Cover	Manning's n for Overland Flow
Smooth asphalt	0.012
Asphalt or concrete paving	0.014
Packed clay	0.03
Light turf	0.20
Dense turf	0.35
Dense shrubbery and forest litter	0.4

Source: N. H. Crawford and R. K. Linsley, "Digital Simulation in Hydrology, Stanford Watershed Model IV" (Ref. 2).



Source: American Society of Civil Engineers, Manual of Engineering Practice No. 37, 1960 (Ref. 3).

Figure 3-10. STANDARD INFILTRATION-CAPACITY CURVES FOR PERVIOUS SURFACE

The first step in the data preparation is the determination of the number of time-steps to be used and the length of each time-step. The time-step length is usually 5 or 10 minutes but may range from 1 to 30 minutes, depending on the length and intensity of storm and the degree of accuracy required. The number of time-steps is limited to a maximum of 150 and should extend past the storm termination sufficiently to account for the storm runoff. Along with the input of time-steps, the number of hyetographs for the drainage basin is needed.

The rainfall data cards are then prepared for each hyetograph from rainfall records or are assumed if a hypothetical test case is being run. The time interval need not be the same as in the flow and quality portion of the Block. The major preparation is forming the tree structure sewer system and dividing the drainage basin into subcatchments. The sewer network is obtained from sewer maps. Pipes smaller than 2-3 feet with no backwater effects, flow dividers, or lift stations are usually designated as gutter/pipes for computation by the Runoff Block. These pipes are not connected to one another by manholes but join directly and lead to an inlet manhole for further routing by TRANSPORT. Once the sewer system is labeled with numbers less than 1,000, the subcatchment areas are formed reflecting the existing sewer network, ground cover, and land slope. Data cards are then made up for each numbered subcatchment, defined by its width, area, slope, percent imperviousness, etc., along with the gutter/pipe or inlet manhole into which the flows are routed. Next, the gutter/pipe cards are punched giving the required information.

the final data cards for the surface flow portion of the block are output control cards. The first two, NSAVE and ISAVE(I), designate the inlet manholes to which enter flows and pollutants are routed for further simulation by the Transport Block. The last four cards are for printing and plotting out inlet hydrographs and pollutographs for the user.

Surface Quality

Data input to this surface quality program are prepared at the same time as the rest of the Runoff Block. Thus, when an inlet drainage basin is selected, it may be subdivided into areas containing a single type of land use. Five land uses which may be modeled are: single family residential, multi-family residential, commercial, industrial, and undeveloped or parklands.

Once the basin is broken into subareas the number of areas, along with other control information such as start time, number of time-steps, and print control, is specified on the first SFQUAL data card. The time interval and number of time-steps to be modeled depends on the interval and length of runoff values provided. Time-steps in multiples of those for which runoff values are provided may be used if desired, but will usually be the same as for subroutine RUNOFF. The actual format for the data cards is shown in Table 3-2.

The program may be used with runoff from a design storm or an actual storm. If an actual storm is being modeled, the number of dry days prior to that storm is determined from rainfall records. Otherwise, the number of dry days is part of the information associated with a design storm.

In determining dry days from actual storms the real number of continuous antecedent days without rainfall should be increased to allow for residual surface solids from the earlier storms. A suggested starting estimate for dry days is the total consecutive antecedent days until the sum of daily rainfalls equals or exceeds 1.0 inch. If a sizable storm (rainfall greater than 0.3 inch) occurs within the four days prior to the test storm the earlier storm should also be modeled. The equivalent dry days should then be calculated using the actual surface residual plus the between-storm accumulation.

The data needed on the frequency of street cleaning and the number of passes made by the sweeper can be found from a public works department.

The number of catchbasins (gutter inlets) per acre may be estimated from visual observation or obtained from a public works department. The volume of liquid remaining in the catchbasins may be found by analysis of the construction drawings. The BOD of the remaining liquid can be estimated or measured.

The last data cards, each defining an individual subarea, provide the model with the subarea number, the inlet manhole number receiving the pollutant outflows, type of land use, area, and the length of gutters for each area. Land use information may be obtained from a governmental planning department, direct observation, or by other means. The length of gutters within each subarea may be obtained by scaling them from a street map.

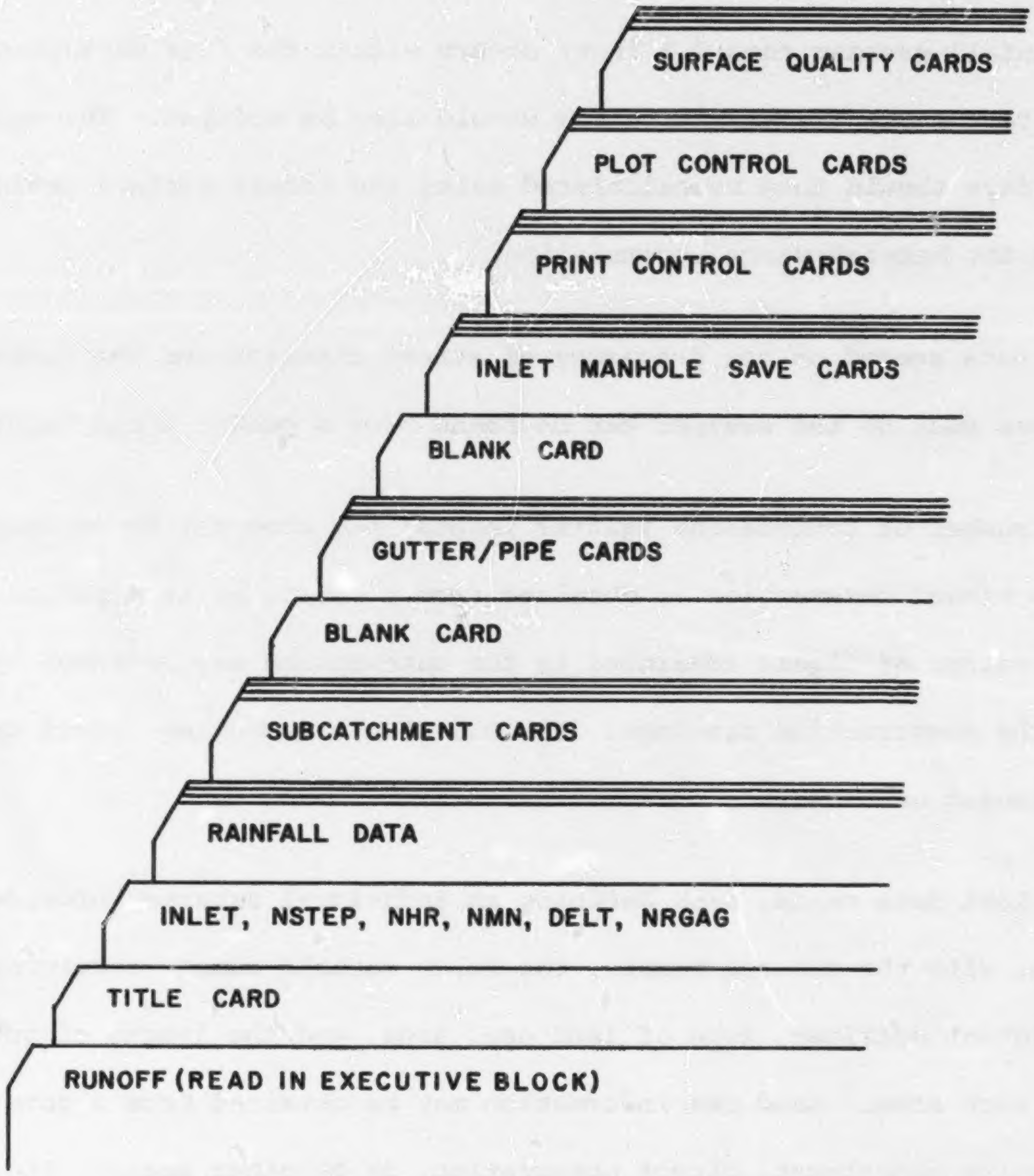

SURFACE QUALITY CARDS
PLOT CONTROL CARDS
PRINT CONTROL CARDS
INLET MANHOLE SAVE CARDS
BLANK CARD
GUTTER/PIPE CARDS
BLANK CARD
SUBCATCHMENT CARDS
RAINFALL DATA
INLET, NSTEP, NHR, NMN, DELT, NRGAG
TITLE CARD
RUNOFF (READ IN EXECUTIVE BLOCK)

Figure 3-11. DATA DECK FOR THE RUNOFF BLOCK

Table 3-2. RUNOFF BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	20A4		Title cards: two cards with heading to be printed on output.	TITLE	none
2			Control card: one card.		
	2I5	1-5	Number of inlets.	INLET	none
		6-10	Number of time-steps to be calculated.	NSTEP	none
	I3	11-13	Hour of start of storm (24-hour clock).	NHR	none
	I2	14-15	Minutes of start of storm.	NMN	none
	F5.1	16-20	Integration period (min).	DELT*	none
	I5	21-25	Number of hyetographs.	NRGAG	none
	F5.0	26-30	Percent of impervious area with zero detention (immediate runoff).	PCTZER	25.0
3			Rainfall control card.		
	I5	1-5	Number of data points for each hyetograph.	NHISTO	none
	F5.0	6-10	Time interval between values (min).	THISTO*	none
			REPEAT CARD GROUP 4 FOR EACH HYETOGRAPH.		
4**			Rainfall hyetograph cards: 10 intervals per card.		
	10F5.0	1-5	Rainfall intensity, first interval (in./hr).	RAIN(1)*	none
		6-10	Rainfall intensity, second interval (in./hr).	RAIN(2)*	none
		11-15	Rainfall intensity, third interval (in./hr).	RAIN(3)*	none
		16-20	Rainfall intensity, fourth interval (in./hr).	RAIN(4)*	none
		⋮		⋮	
			REPEAT CARD 5 FOR EACH SUBCATCHMENT.		
5			Subcatchment cards (3I5, 10F5.0, F10.5): one card per subcatchment.		
	3I5	1-5	Hyetograph number (Based on the order in which they are read in).	JK	1

---

*Decimal point should be punched in this field.

**Problems occur when 0.0 rainfall occurs several time-steps before the actual start of the rainfall (the computer underflows).

NOTE: All non-decimal numbers must be right-justified.

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		6-10**	Subcatchment number.****	N	none
		11-15**	Gutter or manhole number for drainage.****	NGOTO	none
	10F5.0	16-20	Width of subcatchment (ft).***	WWIDTH=W1*	none
		21-25	Area of subcatchment (acres).	WAREA =W2*	none
		26-30	Percent imperviousness of subcatchment.	PCIMP =W3*	none
		31-35	Ground slope (ft/ft).	WSLOPE=W4*	0.030
		36-40	Impervious area } Resistance Factor.	W5 =W5*	0.013
		41-45	Pervious area }	W6 =W6*	0.250
		46-50	Impervious area } Retention storage (in.).	WSTORE=W7*	0.062
		51-55	Pervious area }	WSTORE=W8*	0.184
		56-60	Maximum infiltration rate (in./hr).	WLMAX =W9*	3.00
		61-65	Minimum infiltration rate (in./hr).	WLMIN =W10*	0.52
	F10.5	66-75	Decay rate of infiltration (1/sec).	DECAY =W11*	0.00115
6			Blank card to terminate subcatchment cards: one card.		
			REPEAT CARD 7 FOR EACH GUTTER/PIPE		
7			Gutter/pipe cards: one card per gutter/pipe (if none, leave out).		
	4I5	1-5	Hyetograph number.	NHYET	none
		5-10	Gutter number.	N	none
		11-15	Gutter or manhole number for drainage.	NGOTO	none
		16-20	= 1 for gutter = 2 for pipe.	NP	none
	7F8.0	21-28	Bottom width of gutter or pipe diameter (ft).	GWIDTH=G1*	none
		29-36	Length of gutter (ft).	GLEN =G2*	none
		37-44	Invert slope (ft/ft).	GSLOPE=G3*	none
		45-52	Left-hand side slope (ft/ft).	GS1 =G4*	none
		53-60	Right-hand side slope (ft/ft).	GS2 =G5*	none
		61-68	Manning's coefficient.	GN =G6*	none
		69-76	Depth of gutter when full (in.).	DFULL =G7*	10

---

*Decimal point should be punched in this field.
**Need one inlet or gutter/pipe for each subcatchment basin.
***Twice the length of main drainage pipe through the subcatchment.
****Maximum number = 160.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
8*			Blank card to terminate gutter cards: one card.		
9			Manhole save control: one card.		
	I5	1-5	Number of inlet manholes for which entering flows are to be saved on peripheral storage for TRANSPORT.	NSAVE	none
			IF NSAVE=0, SKIP CARDS 10		
10			Manhole save cards: 16 values per card.		
	16I5	1-5	Inlet manhole numbers for which entering flows are saved (same elements that are used by TRANSPORT).	ISAVE(1)	none
		6-10		ISAVE(2)	none
		11-15		ISAVE(3)	none
		⋮		⋮	
				ISAVE(NSAVE)	none
11			Manhole print control: one card.		
	2I5	1-5	Number of inlet manholes for which entering flows are to be printed.	NPRNT	none
		6-10	Number of time-steps between printings.	INTERV	none
			IF NPRNT=0, SKIP CARDS 12		
12			Manhole print cards: 16 values per card.		
	16I5	1-5	Inlet manhole numbers for which entering flows are to be printed.	IPRNT(1)	none
		6-10		IPRNT(2)	none
		11-15		IPRNT(3)	none
		⋮		⋮	
				IPRNT(NPRNT)	none
13			Manhole plot control: one card.		
	3I5	1-5	Number of inlet manholes for which entering flows are to be plotted (maximum = 25).	NPLOT**	none
		6-10	Number of curves per figure (maximum = 5).	NPCV	1

---

*Need this card even though there are no gutter/pipe cards.

**(NPOL + 1)(NPLOT) cannot exceed 150 without changing variable YT(160, 150) size in Common block.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF NPLOT=0, SKIP CARDS 14.		
14			Manhole plot cards: 16 values per card.		
	16I5	1-5		IPLOT(1)	none
		6-10	Inlet manholes in which entering flows are to be plotted.	IPLOT(2)]	none
		11-15		IPLOT(3)	none
		⋮		IPLOT(NPLOT)	none
			THE FOLLOWING CARDS ARE SURFACE QUALITY DATA.		
15			Control card.		
	2I5	1-5	Number of subareas (may exceed number of subcatchments due to multiple land uses) (maximum = 160).	KTNUM	none
		6-10*	Number of inlets.	NINLTS	none
	F5.0	11-15*	Time interval (min).	DT	none
	4I5	16-20*	Hour of start of storm (24-hr clock).	KHOUR	none
		21-25*	Minute of start of storm.	KMIN	none
		26-30*	Number of time-steps.	NTSTEP	none
		31-35	Use 1 for printing output in sentence form, 0 for printing in table form.	NPRINT	none
16			Cleaning data card.		
	2F10.0	1-10	Number of dry days prior to this storm in which the accumulative rainfall is <1.0 in.	DRYDAY	none
		11-20	Cleaning frequency (days).	CLFREQ	none
	I5	21-25	Number of street sweeper passes.	NOPASS	none
17			Catchbasin data card.		
	3F10.0	1-10	Number per acre.	CBDEN	none
		11-20	Concentration of BOD (mg/L), of the stored water in each catchment basin.	CBBOD	none
		21-30	Stored volume in each catchment basin (gal.)	CBVOL	none

---

*These values must be the same as in card group 2.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			REPEAT DATA CARD 18 FOR EACH SUBAREA.		
			(Maximum = 160 subareas).		
18			Subarea data card.		
	3I5	1-5	Number of this subarea.	KNUM	none
		6-10	Inlet number of this subarea.*	INPUT	none
		11-15	Land use =1 for single family residential =2 for multi-family residential =3 for commercial =4 for industrial =5 for undeveloped or park lands.	KLAND	none
	2F10.2	16-25	Area of this subarea (acres).	ASUB	none
		26-35	Total length of gutters for each subarea (hundreds of ft).	GUTTER	none
			END OF RUNOFF BLOCK CARDS.		

---

*All subareas with the same inlet member must be placed together and these groups must be in the order in which the inlets are saved as described by card group 10.

Table 3-3. RUNOFF BLOCK VARIABLES

Variable Name	C*	Description	Units
A		SS removing coefficient	
ASUB	C	Area of subarea	acre
ATOT	C	Total area of subarea draining to all inlets	acre
AVAIL		Fraction of total dust and dirt available at start of time-step	
AVGFLO	C	Average runoff within a time-step	cfs
AXO		Trapezoidal cross-sectional area, starting	sq ft
AX1		Trapezoidal cross-sectional area, final	sq ft
B		SS removing coefficient	
BOD	C	BOD removed at each time-step to the inlet	lb/DT
BODNS		Non-soluble BOD from dust and dirt removed during each time-step	lb/DT
C	C	Removing coefficient	
CBASTM	C	BOD removed during one time-step including both catchbasin and surface area	lb/DT
CBBOD		Concentration of BOD in each catchbasin	mg/L
CBCENT		Pollution removed from the catchbasin	
CBDEN		Density of catchbasin	No./acre
CBINC	C	BOD removed from catchbasins during one time-step	lb/DT
CBLBS	C	BOD remaining after each time-step	lb
CBNUM		Number of catchbasins within a subarea	

Variable Name	C*	Description	Units
CBSUM	C	Sum of the drainage to catchbasin in each time-step	gal.
CBVOL		Volume of liquid remaining in a catchbasin	gal.
CCOLI	C	Concentration of coliform bacteria of a subarea during one time-step	MPN/100 ml
CLEAN		Number of cleanings since last storm	
CLFREQ		Frequency of street sweepings	
CONBOD		Average concentration of BOD during each time-step	mg/L
CONCSS		Average concentration of SS during each time-step	mg/L
CONVER		Factor for converting lb/DT/cfs to mg/L	
CONV2		Integer that converts flow unit from cfs to 100 ml/min	
CURVE		Name of subroutine	
D		Computational variable, internal	
DAX1		Change in trapezoidal cross-sectional area	sq ft
DCORR		Time-step water depth	ft
DD		Dust and dirt accumulation rate for each subarea	
DDELV		Rate of change in volume change	
DECAY	C	Exponential decay rate for infiltration	1/sec
DEL		Time-step change in depth of watershed flow	
DELD	C	Instantaneous pipe diameter in radians	radian
DELR		Newton-Raphson change in depth for correction	
DELT	C	Integration time interval	sec, min
DELT2	C	One half of a time-step	min
DELV		Average volume change	

---

*C = Variable names shared in common blocks.

Table 3-3 (continued)

Variable Name	C*	Description	Units
DF		Sum of volume change plus flow change times time	
DFLOW1		Change in flow	
DFULL		Gutter's maximum depth (for pipes DFULL = 2.62)	in.
DO		Instantaneous depth	ft
DRAIN		Runoff to each catchbasin during each time-step	gal.
DRYDAY		Number of dry days prior to storm	days
DT		Time-step interval	min
DUMMY	C	Dummy common block	
DWP1		Change in wetted perimeter	
D1		Estimated final depth	in.
E		Hundred times average runoff	
ENDTIM		Time of simulation, 24 hour clock	hr
ERROR		Name of error statement	
ERT		Computational variable	
EXPON		Computational variable	
F		Newton-Raphson volume correction (WSHED)	
F		SS removed during one time-step (SFQUAL)	lb/DT
FLOW		Average flow	cfs
FLOWO		Starting flow	cfs
FLOW1		Final flow	cfs
GCON	C	Manning's equation less hydraulic radius	
GDEPTH	C	Instantaneous gutter depth	in.

Variable Name	C*	Description	Units
GFLOW	C	Gutter flow	cfs
GLEN	C	Length of gutter/pipe	ft
GN	C	Manning's roughness coefficient	
GRAPH	XP	Name of subroutine	
GS		Factor in a geometric series	
GSLOPE	C	Slope of gutter/pipe	ft/ft
GS1	C	Gutter side slope, left	ft/ft
GS2	C	Gutter side slope, right	ft/ft
GUTTER	C	Length of gutter in subarea	100-ft
GWIDTH	C	Pipe diameter or gutter width	ft
G1		Read in value of bottom width of gutter or pipe diameter	ft
G2		Read in value of length of gutter	ft
G3		Read in value of invert slope	ft/ft
G4		Read in value of left-hand side slope	ft/ft
G5		Read in value of right-hand side slope	ft/ft
G6		Read in value of Manning's coefficient	
G7		Read in value of depth of gutter when full	in.
HCURVE		Name of subroutine	
HGRAPH	C	Magnitude of variable to be printed in vertical coordinate of the curve	
HISTOG	C	Length of histogram expressed in time	sec
HORIZ	C	Horizontal title unit of hydrograph in time	hr

Table 3-3 (continued)

Variable Name	C*	Description	Units
HTIME	C	Time interval to be printed in the horizontal coordinate of the curve	
HYDRO		Name of subroutine	
I		Bookkeeping integer	
IA		Do loop counter	
IFLG		Surcharge indicator	
IFPRNT		Name of scratch tape	
IHOUR		Hour of start of storm, 24-hour clock	hr
II		Bookkeeping integer	
IJ		Bookkeeping integer	
IK		Bookkeeping integer	
IKOUNT	C		
IMIN		Minute of start of storm	min
INCNT	C	Name of the tape	
IND		Bookkeeping integer, time interval	
INLET		Inlet number	
INPT		Variable which transfer program from tape to compiler	
INPUT	C	Inlet number	
INTCNT		Printing counter	
INTERV	C	Interval integrization cycles for printed hydrographs	
IOUTCT	C	Name of the tape	
IPOINT	C	Internal pointer	
IPRNT	C	Points for which hydrograph will be printed	

Variable Name	C*	Description	Units
ISAVE	C	Points for which hydrograph will be saved	
ISKIP		Number of inlets minus one	
ISUB		Bookkeeping integer	
J		Bookkeeping integer	
JIN	C	Name of input tape	
JJ		Bookkeeping integer	
JK		Bookkeeping integer	
JKL		Do loop counter	
JN	C	Number of input manholes	
JOUT	C	Name of output tape	
JT		Bookkeeping integer	
K		Bookkeeping integer	
KHOUR		Hour of start of storm, 24-hour clock	
KK		Bookkeeping integer	
KL		Do loop counter	
KLAND	C	Land use	
KMIN		Minute of start of storm	min
KNUM	C	Temporary subarea number reset to inlet number	
KOUNT		Computational counter	
KSKIP		Do loop counter for SKIPN	
KSPOT		Bookkeeping integer	
KTNUM		Number of subarea	
KTSTEP		Time-step counter	

Table 3-3 (continued)

Variable Name	C*	Description	Units
L		Bookkeeping integer	
LL		Bookkeeping integer	
M		Bookkeeping integer	
MKOUNT		Computational counter	
MM		Bookkeeping integer	
N		Bookkeeping integer	
NAMEW	C	External subcatchment number	
NCLEAN		Number of cleanings since last storm	
NEW		Bookkeeping integer	
NEXDAY		Number of days after start of storm simulation ends	day
NG	C	Number of gutters	
NGAGP		Number of graphic point	
NGOTO		Gutter number to which watershed drains	
NGTOG	C	Gutter connections	
NGTOI	C	Inlet connections	
NGUT	C	Bookkeeping integer	
NHISTO	C	Number of rainfall time interval	
NHR		Hour of the start of storm	hr
NHYET	C	Number of hyetograph	
NIN	C	Maximum number of gutters draining to gutter, and watersheds draining to gutter	

Variable Name	C*	Description	Units
NINC	C	Do loop counter	
NINLTS		Total number of inlets	
NMN		Minutes of the start of storm	min
NOG	C	Total number of gutters/pipes	
NOLD		Bookkeeping integer	
NOPASS		Number of street sweeper passes	
NOUT		Output file variable	
NP		Read in value of NPG	
NPG	C	Control switch for type of gutter, 1=regular, 2=pipe, 3=dummy connected directly to inlet	
NPRINT		Number of time-steps between printing	
NPRNT	C	Number of points where hydrographs are printed	
NPT	C	Number of points to be plotted	
NQUAL		Number of quality constituents used as zero in Runoff quantity	
NRAIN	C	Number of rainfall	
NRANVL		Rain data points limiter	
NRGAG	C	Number of hyetographs	
NSAVE	C	Number of points where hydrographs are saved	
NSCRAT	C	Name of the tape	
NSHED	C	Number of the watershed	
NSPOT		Bookkeeping integer	
NSTEP	C	Number of time-steps	
NSTOP		Error switch	
NTIMEH		Hour of day of simulation (24-hour clock)	hr

Table 3-3 (continued)

Variable Name	C*	Description	Units
NTQUAL		Scratch output file indentifier	
NTSTEP		Number of time-steps modeled	
NTYPE		Number of types	
NUSTEP		Number of printed hydrograph points	
NW	C	Number of watershed	
NWTOG	C	Gutter connection	
NWTOI		Inlet connection	
NX		Bookkeeping integer	cfs
ORIZ		Horizontal title unit for hydrograph in time	hr
OUTFLW	C	Flow out of the gutter	cfs
P			
PCIMP	C	Percent imperviousness of watershed	%
PCNTCB		Percent removal of BOD by catchbasin of one subarea	%
PCNTSS		Percent removal of SS from total dust and dirt of one subarea	%
PCTBOD		Percent removal of BOD from available surface BOD of one subarea	%
PCTZER	C	Percent of impervious area with zero detention depth	%
PO	C	Soluble BOD in dust and dirt	lb
POCB		Total BOD available from catchbasins	lb
POOCB		BOD available in each catchbasin at start	lb

Variable Name	C*	Description	Units
POP	C	BOD removed from dust and dirt during one time-step	lb/DT
POPSS	C	SS removed during one time-step	lb/DT
QIN	C	Input from upstream gutter	cfs
QSUR	C	Surcharge	cf
RADO		Starting hydraulic radius	ft
RAD1		Final hydraulic radius	ft
RAIN	C	Rainfall	in./hr
REFF		Street sweeper removal efficiency	percent, decimal
REMDD	C	Remaining dust and dirt after each time-step	lb
RHYDRO		Name of subroutine	
RI	C	Instantaneous rainfall rate	in./hr
RLOSS	C	Infiltration loss, instantaneous	in./hr
RUNCFS	C	Instantaneous runoff for each inlet	cfs
RUNOFF		Average runoff over a time-step	in./hr
RUNTMP	C	Flow entering input manholes	cfs
SFCOLI	C	Total coliform in runoff	MPN/min
SFQUAL		Name of subroutine	
SKIP1		Scratch tape variable, unformatted	
SKIP2		Scratch tape variable, unformatted	
SKIP3		Scratch tape variable, unformatted	

Table 3-3 (continued)

Variable Name	C*	Description	Units
SKIP4		Scratch tape variable, unformatted	
SKIP5		Scratch tape variable, unformatted	
SKIP6		Scratch tape variable, unformatted	
SKIP7		Scratch tape variable, unformatted	
SS	C	Suspended solids	lb
SUMBOD		Sum of total surface BOD in each area	lb
SUMCB		Sum of total BOD in catchbasins	lb
SUMDD		Sum of the dust and dirt	lb
SUMI	C	Total infiltration into ground	cf
SUMOFF	C	Total gutter flow @ inlet manhole	cf
SUMQW	C	Total flow for each subcatchment	cf
SUMR	C	Total rainfall	cf
SUMST	C	Total surface storage	cf
T		Time-step interval	hr
TAREA		Total area	acres
TBOD		Total BOD in surface runoff	lb
TCBAST	C	Total BOD removed for each inlet	lb
TCBINC	C	Total BOD removed from catchbasins for each inlet	lb
TCCOLI	C	Total concentration of coliform during one time-step	MPN/ 100 ml
TGS		Sum of the gemetric series plus 1.0	
THISTO		Time of rainfall time intervals	min
TIME	C	Time	sec
TIMEM		Time of simulation (24-hour clock)	min
TIMES		Time of simulation (SFQUAL)	sec
TIME2	C	Time minus half-step	sec
TITEL		Description of curve in horizontal coordinates	
TITL		Description of curve in vertical coordinate	
TITLE	C	Description of problem	
TMAX		Maximum time to be printed in curve	hr
TMINS		Time-step interval	min
TOTDD	C	Total dust and dirt on ground at start of storm for each inlet	lb
TPCBOD		Percent of total BOD removed from each area	%
TPCTBD		Total percent removal of BOD from catchbasin of all areas	%
TPCTCB		Total percent removal of BOD from catchbasin and surface of all areas	%
TPCTSS		Total percent removal of SS from surface of all areas	%
TPOP	C	Total BOD removed from dust and dirt for each inlet	lb
TPOPSS	C	Total SS removed for each inlet	lb
TPTBOD		Total percent removal of BOD from surface of all areas	%
TRAIN	C	Time when rainfall ends	min, sec
TSEC		Time-step interval	sec
TSMBD		Sum of total BOD for the study area	lb

Table 3-3 (continued)

Variable Name	C*	Description	Units
TSUMCB		Sum of the original dust and dirt available in the catchbasin	lb
TSUMDD		Sum of the original dust and dirt available on surface drainage area	lb
TTCBNC		Total removal of BOD from all of catchbasin and surface area	lb
TTCBST		Total removal of BOD of all catchbasins	lb
TTPOP		Total removal of BOD from all surface area	lb
TTPPSS		Total removal of SS of all areas	lb
TZERO		Starting time of the hydrograph	sec
VER		Vertical title unit for hydrograph	in./hr
VERT	C	Vertical title unit for hydrograph	in./hr
WAR		Impervious area of watershed with immediate runoff	sq ft
WAREA	C	Area of watershed	acres, sq ft
WCON	C	Modified Manning's equations, impervious and pervious portions of watershed	
WDEPTH	C	Instantaneous depth on watershed	ft
WFLO		Average watershed flow during time interval	cfs
WFLOW	C	Instantaneous flow from watershed	cfs
WLMAX	C	Maximum infiltration rate	in./hr
WLMIN	C	Minimum infiltration rates	in./hr
WN	C	Dummy variable	
WPO		Wetted parameter, starting	ft
WP1		Wetted parameter, final	ft
WSHED		Name of subroutine	
WSLOPE	C	Average slope of watershed	ft/ft
WSTORE	C	Minimum and maximum storage depth on surface of watershed	ft
WWIDTH	C	Average width of watershed	ft
W1		Read in value of the average width of watershed	ft
W2		Read in value of the area of watershed	acre
W3		Read in value of the percent of imperviousness	%
W4		Read in value of slope of watershed	ft/ft
W5		Resistance factor for impervious area	
W6		Resistance factor for pervious area	
W7		Retention storage for impervious area	in.
W8		Retention storage for pervious area	in.
W9		Read in value of maximum infiltration rate	in./hr
W10		Read in value of minimum infiltration rate	in./hr
W11		Read in value of decay rate of infiltration	1/sec
X	C	Number of time interval used in the horizontal coordinate	
XLAB	C	Minimum point in the horizontal scale	
Y		Number of point used in the vertical coordinate	
YLAB	C	Minimum point in the vertical scale	

EXAMPLES

Two examples are given, one for rainfall runoff and the other for quality runoff.

Example 1 - Surface Flows

The "fine" schematization of the Northwood (Baltimore) test area is used as an example; the area is shown in Figures 3-8 and 3-12. A sample of the data cards is shown in Table 3-4. Selected output pages are reproduced in Tables 3-5 through 3-10 and in Figures 3-13 and 3-14.

Example 2 - Surface Quality

A portion of a combined sewer area is shown in Figure 3-15. It is a copy of a U.S. Geological Survey topographic map (7-1/2 minute). The drainage basin was determined for the Runoff program as was the inlet numbering.

As an example consider only one of the numbered inlets for a computer run. The land use for the area draining to inlet number 65 was determined by zoning maps. This information is used to determine the subareas (each having one type of land use) within each inlet drainage basin. The area of each subarea and the length of gutters within it are measured from the map. The subareas of inlet drainage basin 65 and the input data for this basin are also shown in Figure 3-15. The subareas are numbered for informational purposes only (i.e., they are not used in the execution of the program).

Information about the number of catchbasins per acre and volume of liquid remaining in the catchbasins was gathered from the public works department. The average BOD of the liquid remaining in the catchbasins was estimated.

For this example the catchbasin density is 1 per acre, the volume of liquid remaining is 150 gallons, and the BOD is 100 mg/L.

The data for frequency of street sweeping and number of passes were obtained from the public works department. For this example the frequency is 14 days and there were two passes. The number of dry days preceding the start of the runoff being modeled was found from rainfall records to be 50 days.

The clock time of the start of rainfall was also determined from rainfall records. The time-step to be used is that which the Runoff program used or 10 minutes. The time selected will depend to some extent upon the observed data used as input, i.e., rainfall, or that used to check output, i.e., runoff hydrographs. The number of time-steps modeled here is 30, or 5 hours. The runoff for each inlet was found from the Runoff program.

Sample input for this example is shown in Table 3-11 and the output for the computer run made is shown in Tables 3-12 and 3-13.

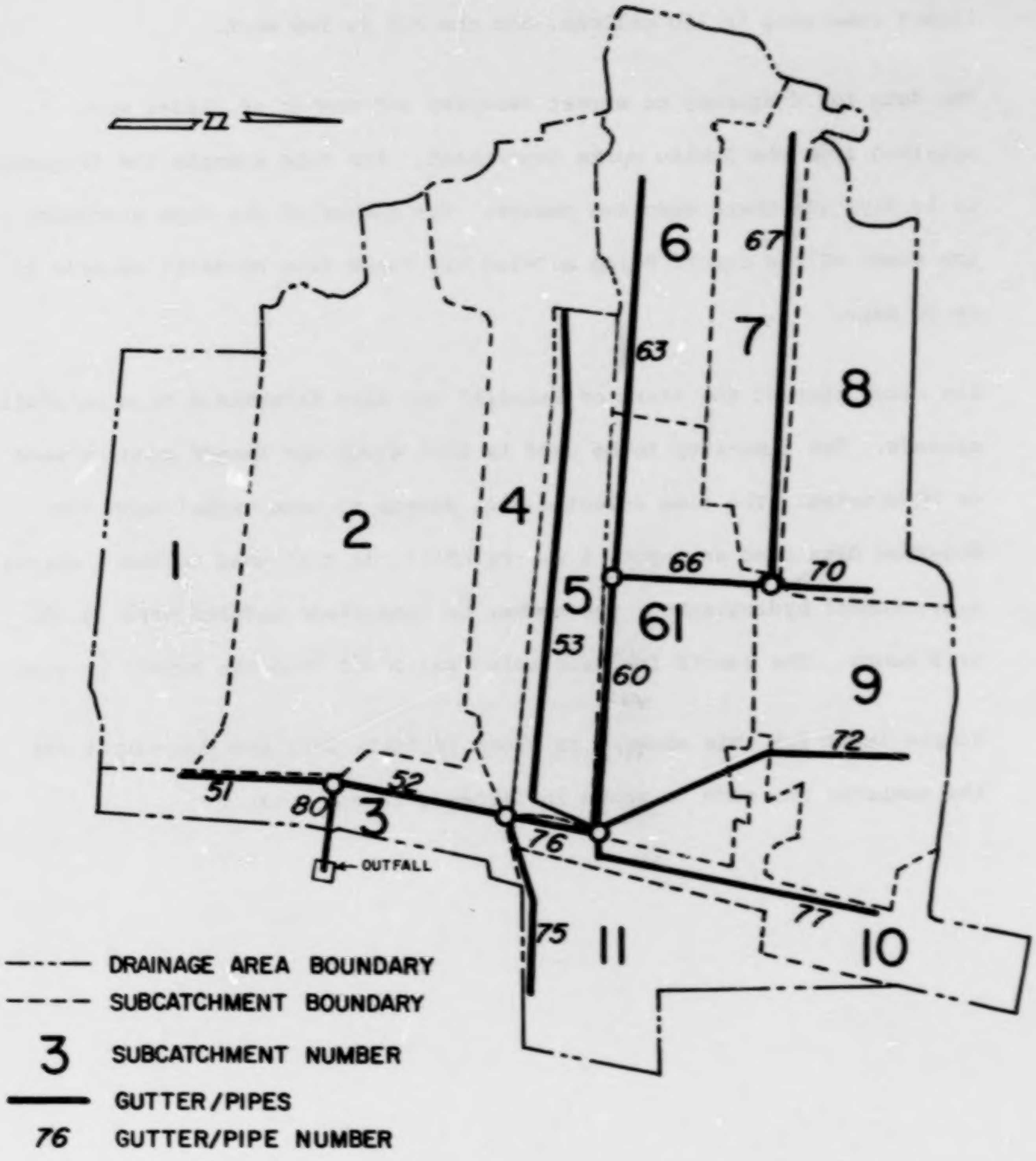

6
67
7
8
63
4
2
1
5
66
70
61
53
60
9
72
51
52
80
3
76
OUTFALL
75
11
77
10
DRAINAGE AREA BOUNDARY
SUBCATCHMENT BOUNDARY
3 SUBCATCHMENT NUMBER
GUTTER/PIPES
76 GUTTER/PIPE NUMBER

Figure 3-12. NORTHWOOD (BALTIMORE) GUTTER/PIPES "FINE" PLAN

Table 3-4. TYPICAL DATA CARDS

DATA	CARD GROUP NO.
AFTERNOON STORM OF 8-1-65	1
RUNOFF BLOCK ONLY	2
1 100 1. 1	3
60 1.	4
1.20 1.08 0.24 1.14 0.24 0.24 0.72 1.56 1.80 2.58	
3.06 3.54 2.56 2.94 2.10 0.84 0.96 1.80 1.38 1.20	
0.72 0.72 1.02 0.54 0.36 0.30 0.24 0.30 0.42 0.24	
0.18 0.12 0.06 0.12 0.12 0.06 0.00 0.00 0.00 0.00	
1 1 51 250. 4.47 58	5
1 2 80 430. 9.05 60	
1 3 80 750. 1.99 36	
1 4 52 120. 4.44 69	
1 5 531200. 2.68 99	
1 6 63 780. 3.64 71	
1 61 60 550. 4.47 99	
1 7 67 800. 2.83 85	
1 8 70 230. 4.05 48	
1 9 72 650. 4.19 95	
1 10 77 800. 2.71 49	
1 11 75 280. 2.89 87	6
1 51 80 2 1.75 260. 0.02 0.0 0.0 .012	7
1 52 80 2 3.5 320. 0.007 .012	
1 53 76 2 1.25 600. 0.041 .012	
1 60 76 2 2.5 470. 0.04 .012	
1 63 60 2 1.75 810. 0.04 .012	
1 66 60 2 2.0 150. 0.036 .012	
1 67 66 2 1.5 420. 0.026 .012	
1 70 66 2 1.5 150. 0.03 .012	
1 72 76 2 2.0 335. 0.036 .012	
1 77 76 2 1.5 550. 0.04 .012	
1 76 52 2 2.75 219. 0.043 .012	
1 75 52 2 1.5 290. 0.04 .012	
1 80 0 2 4.0 121. 0.0085 .012	8
	9
1	10
80	11
5 5	12
52 60 66 76 80	13
1	14
80	

Table 3-5. TYPICAL OUTPUT, GENERAL INFORMATION

```
    ENTRY MADE TO RUNOFF MODEL
AFTERNOON STORM OF 8-1-65
RUNOFF BLOCK ONLY


INLET NUMBER    1

NUMBER OF  TIME  STEPS  100

INTEGRATION TIME INTERVAL (MINUTES),     1.00

25.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH

FOR     60 RAINFALL STEPS, THE TIME INTERVAL IS   1.00 MINUTES

FOR RAINGAGE NUMBER   1   RAINFALL HISTORY IS

      1.20      1.08      0.24      1.14      0.24      0.24      0.72      1.56      1.80      2.58
      3.06      3.54      2.56      2.94      2.10      0.64      0.96      1.80      1.38      1.20
      0.72      0.72      1.02      0.54      0.36      0.30      0.24      0.30      0.42      0.24
      0.18      0.12      0.06      0.12      0.12      0.06      0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

Table 3-6. TYPICAL SUBCATCHMENT OUTPUT

```
SUBAREA   GUTTER    WIDTH   AREA  PERCENT   SLOPE   RESISTANCE FACTOR  SURFACE STORAGE(IN)    INFILTRATION RATE(IN/HR)   GAGE
NUMBER  OR MANHOLE  (FT)    (AC)  IMPERV.  (FT/FT)   IMPERV.   PERV.    IMPERV.    PERV.    MAXIMUM MINIMUM DECAY RATE   NO
   1        51      250.     4.     58.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   2        80      430.     9.     60.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   3        80      750.     2.     36.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   4        52      120.     4.     69.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   5        53     1200.     3.     99.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   6        63      780.     4.     71.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
  61        60      550.     4.     99.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   7        67      800.     3.     85.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   8        70      230.     4.     48.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
   9        72      650.     4.     95.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
  10        77      800.     3.     49.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1
  11        75      280.     3.     87.0    0.030     0.013    0.250     0.062     0.184      3.00    0.52    0.00115     1

TOTAL NUMBER OF SUBCATCHMENTS,  12

TOTAL TRIBUTARY AREA (ACRES),   47.41
```

Table 3-7. TYPICAL GUTTER/PIPE OUTPUT

```
GUTTER     GUTTER      WIDTH   LENGTH    SLOPE    SIDE SLOPES    MANNING    OVERFLOW
NUMBER   CONNECTION     (FT)    (FT)    (FT/FT)    L      R         N         (IN)

  51*        80         1.8     260.    0.020     0.0    0.0      0.012       0.0
  52*        80         3.5     320.    0.007     0.0    0.0      0.012       0.0
  53*        76         1.3     600.    0.041     0.0    0.0      0.012       0.0
  60*        76         2.5     470.    0.040     0.0    0.0      0.012       0.0
  63*        60         1.8     810.    0.040     0.0    0.0      0.012       0.0
  66*        60         2.0     150.    0.036     0.0    0.0      0.012       0.0
  67*        66         1.5     420.    0.026     0.0    0.0      0.012       0.0
  70*        66         1.5     150.    0.030     0.0    0.0      0.012       0.0
  72*        76         2.0     335.    0.036     0.0    0.0      0.012       0.0
  77*        76         1.5     550.    0.040     0.0    0.0      0.012       0.0
  76*        52         2.8     219.    0.043     0.0    0.0      0.012       0.0
  75*        52         1.5     290.    0.040     0.0    0.0      0.012       0.0
  80*         0         4.0     121.    0.008     0.0    0.0      0.012       0.0

TOTAL NUMBER OF GUTTERS/PIPES,  13

ASTERISK (*) DENOTES CIRCULAR PIPE, DIAMETER=.WIDTH.
```

Table 3-8. COMPUTED ARRANGEMENT OF SUBCATCHMENTS AND GUTTER/PIPES

```
ARRANGEMENT OF SUBCATCHMENTS AND GUTTERS/PIPES
  GUTTER    TRIBUTARY GUTTER/PIPE                                       TRIBUTARY SUBAREA
    51                                                                    1
    52       76   75                                                      4
    53                                                                    5
    60       63   66                                                     61
    63                                                                    6
    66       67   70
    67                                                                    7
    70                                                                    8
    72                                                                    9
    75                                                                   11
    76       53   60   72   77
    77                                                                   10
    80       51   52                                                      2   3
  INLET     TRIBUTARY GUTTER-PIPE-MANHOLE                               TRIBUTARY SUBAREA
     1       80
HYDROGRAPHS WILL BE  STORED FOR THE FOLLOWING    1 POINTS
    80
```

Table 3-9. PRINTED OUTPUT OF SELECTED HYDROGRAPHS

```
HYDROGRAPHS ARE LISTED FOR THE FOLLOWING    5 POINTS
    TIME          52         60         66         76         80
 0   5.00        1.15       0.76       0.34       1.14       1.02
 0  10.00       12.99       7.81       3.32      12.40      14.07
 0  15.00       59.59      28.58      11.11      49.56      77.33
 0  20.00       38.38      17.60       6.68      29.96      52.33
 0  25.00       24.43      10.59       3.97      18.23      34.24
 0  30.00       13.30       5.65       2.09       9.47      19.08
 0  35.00        7.81       3.15       1.14       5.31      11.43
 0  40.00        4.40       1.67       0.60       2.81       6.58
 0  45.00        2.54       0.92       0.32       1.51       3.86
 0  50.00        1.64       0.57       0.20       0.92       2.50
 0  55.00        1.13       0.38       0.13       0.61       1.73
 1   0.0         0.83       0.27       0.09       0.43       1.26
 1   5.00        0.63       0.20       0.07       0.31       0.96
 1  10.00        0.49       0.15       0.05       0.24       0.75
 1  15.00        0.39       0.12       0.04       0.19       0.60
 1  20.00        0.32       0.10       0.03       0.15       0.48
 1  25.00        0.26       0.08       0.03       0.12       0.40
 1  30.00        0.22       0.07       0.02       0.10       0.34
 1  35.00        0.19       0.05       0.02       0.08       0.28
 1  40.00        0.16       0.05       0.02       0.07       0.24
```

Table 3-10. COMPUTED RAINFALL INFORMATION

```
TOTAL RAINFALL (CU FT)                                      105241.
TOTAL INFILTRATION (CU FT)                                   30579.
TOTAL GUTTER FLOW AT INLET (CU FT)                           68199.
TOTAL SURFACE STORAGE AT END OF STORM (CU FT)                 6231.
ERROR IN CONTINUITY, PERCENTAGE OF RAINFALL,                0.22029
```

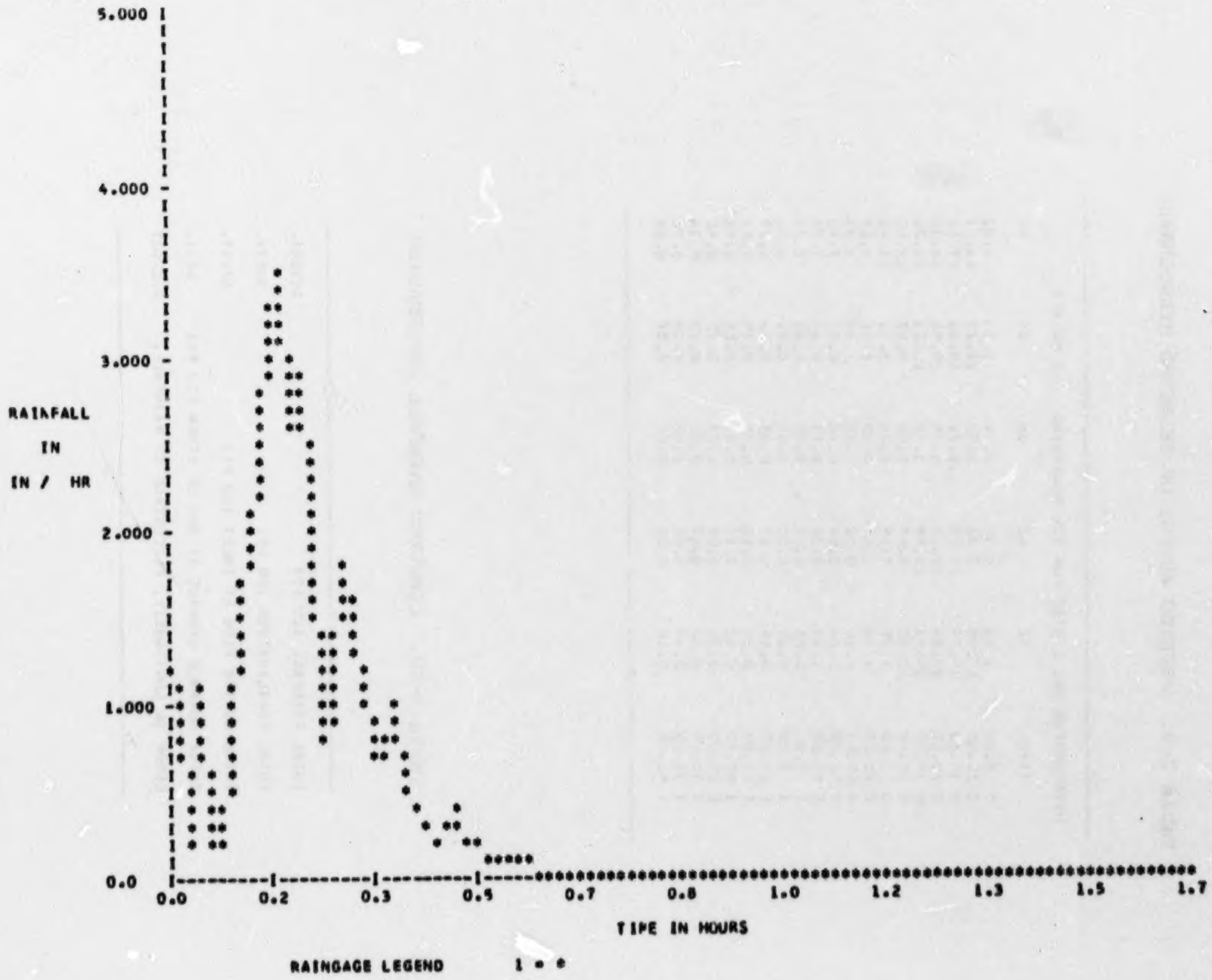


Figure 3-13. TYPICAL OUTPUT HYETOGRAPH

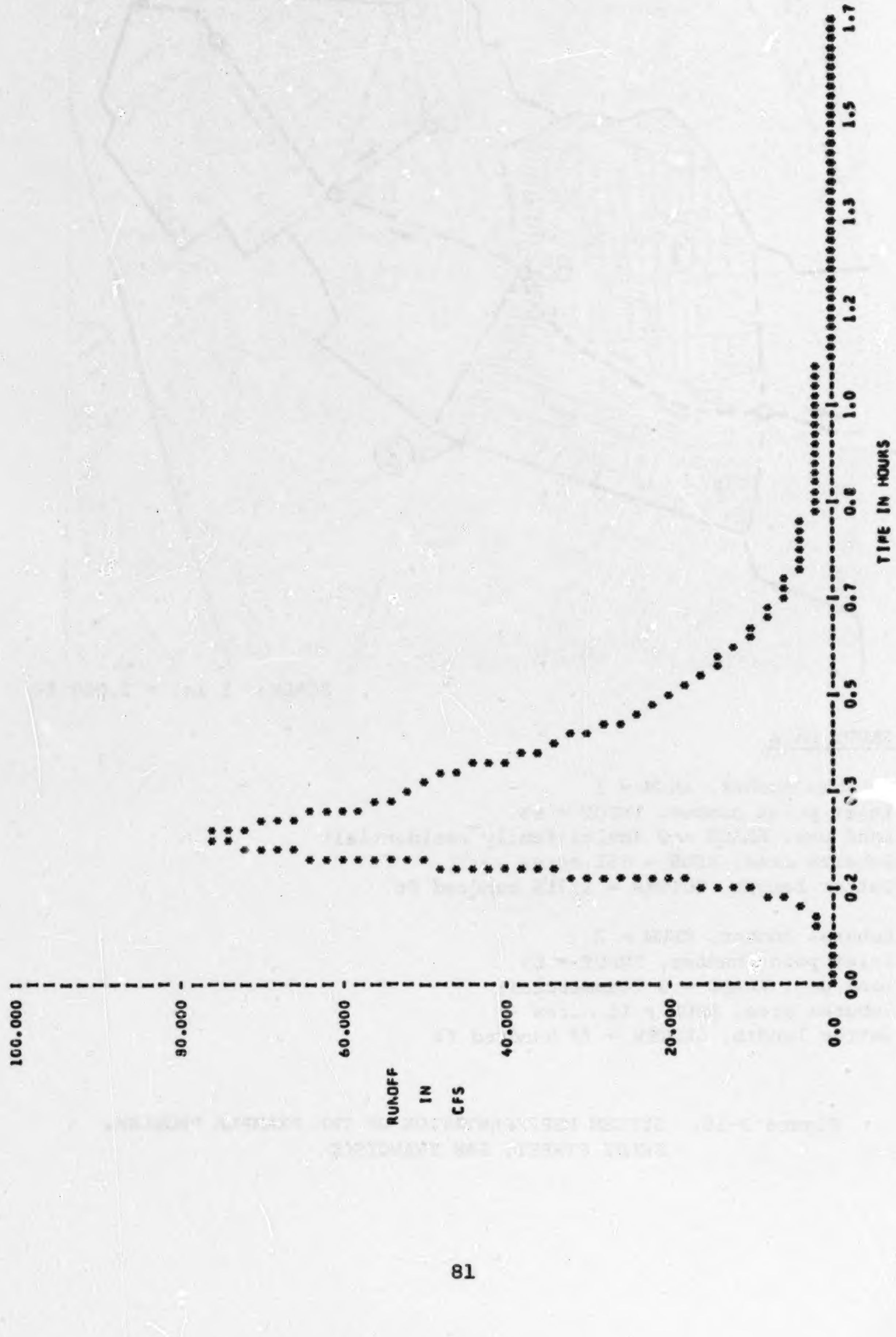
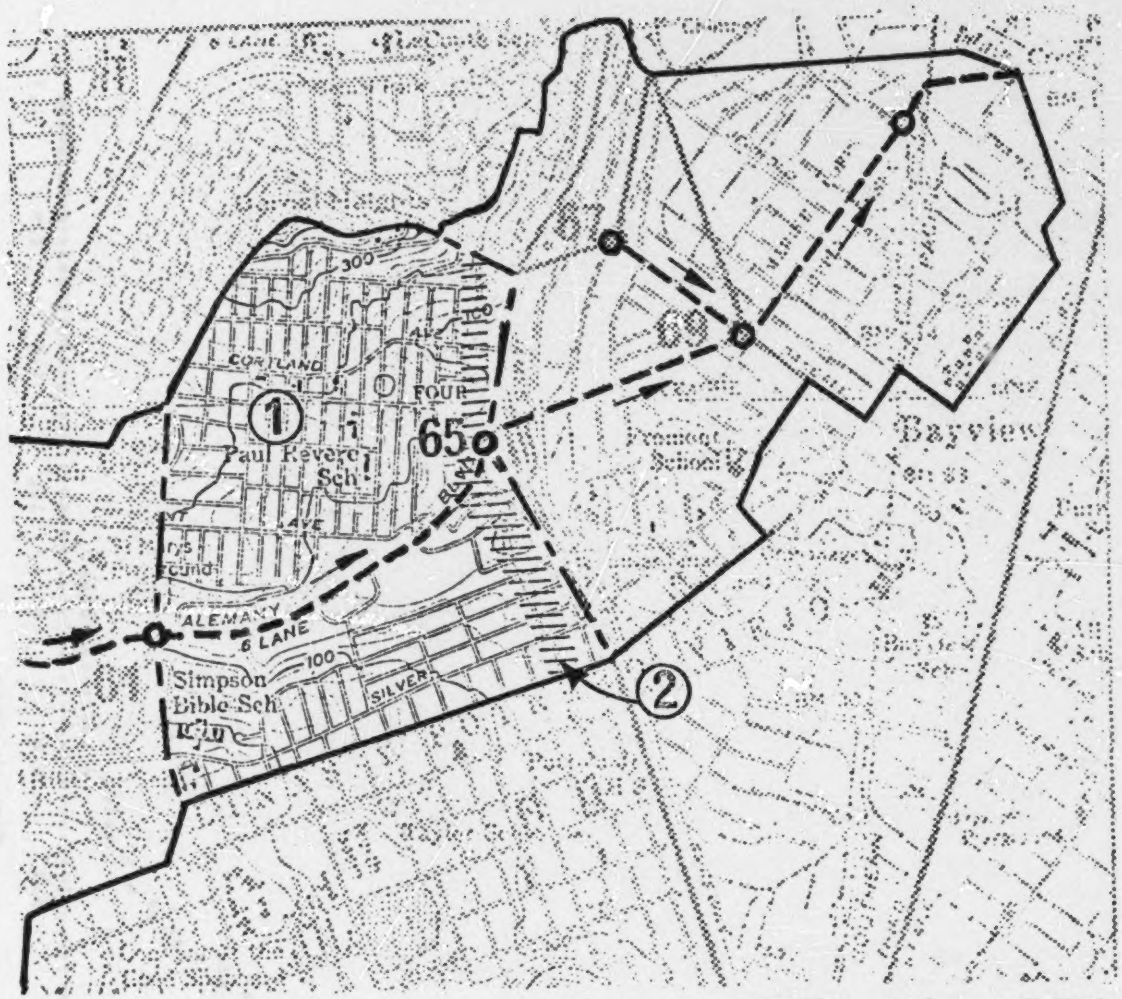


Figure 3-14. TYPICAL OUTPUT HYDROGRAPH


1
65
67
69
2
61
300
100
CORTLAND
FOUR
Paul Revere Sch
ALEMANY
6 LANE
Simpson Bible Sch
SILVER
Bayview

SCALE: 1 in. = 2,000 ft

INPUT DATA

Subarea number, KNUM = 1
Inlet point number, INPUT = 65
Land use, KLAND = 2 (multi-family residential)
Subarea area, ASUB = 351 acres
Gutter length, GUTTER = 1,716 hundred ft

Subarea number, KNUM = 2
Inlet point number, INPUT = 65
Land use, KLAND = 3 (commercial)
Subarea area, ASUB = 15 acres
Gutter length, GUTTER = 72 hundred ft

Figure 3-15. SYSTEM REPRESENTATION OF THE EXAMPLE PROBLEM, SELBY STREET, SAN FRANCISCO

Table 3-11. EXAMPLE PROBLEM DATA INPUT, SURFACE QUALITY

DATA						CARD GROUP NO.
2	1	10.	8	55	30	15
	50.		14.	2		16
	1.		100.		150.	17
1	65	2	351.00		1716.00	18
2	65	3	15.00		72.00	

Table 3-12. EXAMPLE PROBLEM OUTPUT, SURFACE QUALITY, GENERAL INFORMATION

```
NUMBER OF SUBAREAS, KTNUM =  2
NUMBER OF INLETS,   NINLTS =  1
TIME INTERVAL (MIN),    DT = 10.00
STORM START TIME (HR:MIN) =  8:55

DRYDAY =        50., CLFREQ=        14., NOPASS =    2

AVERAGE NO. CB/ACRE,     CBDEN =          1.
CB CONTENTS BOD (MG/L), CBBOD =        100.
CB STORED VOLUME (GAL), CBVOL =        150.
```

Table 3-13. EXAMPLE PROBLEM OUTPUT, SURFACE QUALITY, CALCULATED VOLUMES

```
                  TOTAL QUANTITIES REMOVED FROM THE AREA SERVING INPUT NO.  65,
                        DURING EACH TIME INCREMENT FOR  30 TIME STEPS

LAND USES TO THIS INLET         AREA    LENGTH OF GUTTERS   DUST & DIRT PRIOR   SOLUBLE BOD PRIOR
                               ACRES    HUNDREDS OF FEET      TO STORM, LBS.      TO STORM, LBS.
MULTI-FAMILY RESIDENTIAL:     351.00             1716.00            60057.45              216.21
COMMERCIAL:                    15.00               72.00             3615.50               27.84

                      SUSPENDED SOLIDS      FIVE-DAY BIOCHEMICAL OXYGEN DEMAND
  TIME    RUNCFS   (POPSS)   (CONCSS)    (CBINC) +   (POP) =(CBASTM)  (CONBOD)
             CFS    LBS/DT       MG/L    LBS/DT     LBS/DT   LBS/DT       MG/L
  8:55      0.00      0.00       0.00      0.00       0.00     0.00       0.00
  9: 5      0.00      0.00       0.00      0.00       0.00     0.00       0.00
  9:15      0.00      0.00       0.00      0.00       0.00     0.00       0.00
  9:25      0.33      3.27     529.13      0.78       0.48     1.25     203.10
  9:35      3.46     82.24    1159.11      5.83       7.55    13.38     188.58
  9:45      7.67    515.00    2471.75     10.71      34.55    45.26     217.25
  9:55     11.63   1207.99    3343.49     12.02      72.18    84.19     233.03
 10: 5     15.59   1474.09    2892.88      8.86      85.57    94.43     185.33
 10:15     19.23    697.29    1069.73      4.77      45.79    50.56      77.56
 10:25     21.78    451.47     588.07      1.94      32.63    34.57      45.03
 10:35     27.84    462.83     498.27      0.67      33.55    34.21      36.83
 10:45     35.63    633.16     532.89      0.18      43.65    43.83      36.89
 10:55     34.18    721.53     552.12      0.03      48.18    48.22      36.89
 11: 5     41.32    809.24     572.56      0.00      52.53    52.53      37.17
 11:15     52.67   1162.62     660.77      0.00      71.82    71.82      40.82
 11:25     71.47   1864.93     802.50      0.00     109.30   109.30      47.03
 11:35     82.57   2663.45     923.65      0.00     150.29   150.29      52.12
 11:45     88.00   3049.20     954.94      0.00     168.34   168.34      52.72
 11:55     60.94   2237.87     802.63      0.00     123.54   123.54      44.31
 12: 5     46.82   1191.65     590.73      0.00      66.90    66.90      33.16
 12:15     39.80    790.86     487.72      0.00      44.83    44.83      27.65
 12:25     36.03    617.79     435.20      0.00      35.13    35.13      24.74
 12:35     27.00    445.97     377.96      0.00      25.56    25.56      21.66
 12:45     17.33    249.74     300.94      0.00      14.65    14.65      17.66
 12:55     11.90    132.26     241.71      0.00       7.98     7.98      14.59
 13: 5      8.59     80.05     208.69      0.00       4.94     4.94      12.87
 13:15      6.44     53.09     188.70      0.00       3.33     3.33      11.83
 13:25      4.97     37.55     175.82      0.00       2.38     2.38      11.15
 13:35      3.93     27.84     167.10      0.00       1.78     1.78      10.69
 13:45      3.18     21.43     161.03      0.00       1.38     1.38      10.36

  POUNDS REMOVED  21684.36                45.79    1288.80  1334.59
```

SECTION 4

TRANSPORT BLOCK

Page

BLOCK DESCRIPTION 87

- Broad Description of Flow Routing 89
- Broad Description of Quality Routing 89

SUBROUTINE DESCRIPTIONS 90

- Subroutine TRANS 90
- Subroutine TSTRDT 95
- Subroutine SLOP 95
- Subroutine FIRST 99
- Subroutine INFIL 99
  - Dry Weather Infiltration (DINFIL) 103
  - Residual Melting Ice and Frost Infiltration (SINFIL) 105
  - Antecedent Precipitation (RINFIL) 107
  - High Groundwater Table (GINFIL) 108
  - Apportionment of Infiltration 108
  - Hydrologic Data 109
  - Sewer Data 110
- Subroutine FILTH 110
  - Quantity Estimates 112
  - Quality Estimates 120
- Subroutine DWLOAD 123
- Subroutine INITAL 124
- Subroutine ROUTE 124
  - Conduit Routing (NTYPES 1 to 15 Inclusive) 126
  - Routing in Manholes (NTYPE = 16) 131
  - Routing at Lift Stations (NTYPE = 17) 131
  - Routing at Flow Dividers (NTYPE = 18 and 21) 131
  - Routing at a Flow Divider (NTYPE = 20) 131
  - Routing Through a Storage Element (NTYPE = 19) 133
  - Routing at a Backwater Element (NTYPE = 22) 136
- Subroutine QUAL 136
- Subroutine PRINT 138
- Subroutine TSTCST 138

Page

Support Subroutines and Functions 138
Block Data 141
Function DEPTH 141
Function DPSI 141
Subroutine FINDA 141
Subroutine NEWTON 143
Function PSI 143
Function RADH 143
Subroutine TINTRP 143
Function VEL 143

INSTRUCTIONS FOR DATA PREPARATION 146

Transport Model 146
Step 1 - Theoretical Data 149
Step 2 - The Physical Representation of the Sewer System 151
Step 3 - Input Data and Computational Controls 162
Internal Storage Model 163
Step 1 - Call 163
Step 2 - Storage Description: Part 1 163
Step 3 - Output 163
Step 4 - Storage Description: Part 2 163
Step 5 - Unit Costs 163
Infiltration Model 164
Step 1 - Determine Groundwater Condition 164
Step 2 - Build Up Infiltration from Base Estimates 164
Dry Weather Flow Model 165
Step 1 - Establishing Subareas 165
Step 2 - Collection of Data 167
Step 3 - Data Tabulation 167

EXAMPLES 194

Example 1 - Transport Block 194
Description of Sample Data 194
Description of Sample Output 198
Example 2 - Subroutine INFIL 205
Example 3 - Subroutine FILTH 216

SECTION 4

TRANSPORT BLOCK

BLOCK DESCRIPTION

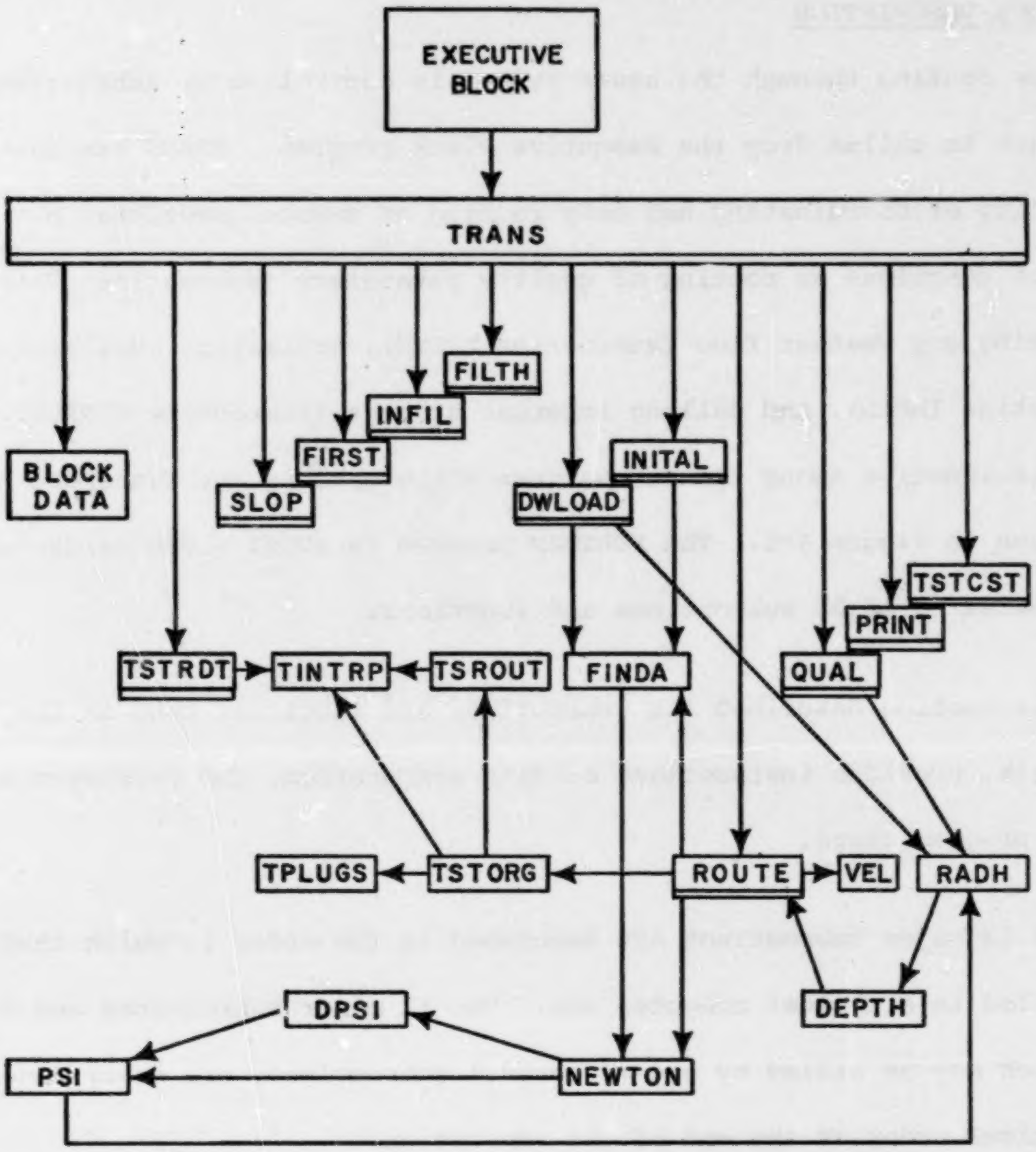
Flow routing through the sewer system is controlled by subroutine TRANS which is called from the Executive Block program. TRANS has the responsibility of coordinating not only routing of sewage quantities but also such functions as routing of quality parameters (subroutine QUAL), estimating dry weather flow (subroutine FILTH), estimating infiltration (subroutine INFIL), and calling internal storage (subroutine TSTRDT). The relationships among the subroutines which make up the Transport Block are shown in Figure 4-1. The FORTRAN program is about 4,050 cards long, consisting of 25 subroutines and functions.

This section describes the subroutines and functions used in the Transport Block, provides instructions on data preparation, and furnishes examples of program usage.

The 12 major subroutines are described in the order in which they are called in a typical computer run. The 11 minor subroutines and functions, which may be called by any of several subroutines, are described in alphabetical order at the end of the subsection.

Instructions are provided for these subroutines requiring card input data, namely: transport, internal storage, infiltration, and DWF.

Examples, with sample I/O data, are given for transport, infiltration, and DWF computations. Internal storage procedures are similar to those described in Section 5; hence they are not presented here.


EXECUTIVE BLOCK
TRANS
BLOCK DATA
SLOP
FIRST
INFIL
FILTH
DWLOAD
INITAL
TSTCST
PRINT
TSTRDT
TINTRP
TSROUT
FINDA
QUAL
TPLUGS
TSTORG
ROUTE
VEL
RADH
DEPTH
DPSI
PSI
NEWTON

Note: Arrows point from the calling program to the called program. Boxes with double underline represent major subroutines.

Figure 4-1. TRANSPORT BLOCK

Broad Description of Flow Routing

To categorize a sewer system conveniently prior to flow routing, each component of the system is classified as a certain type of "element." All elements in combination form a conceptual representation of the system in a manner similar to that of links and nodes. Elements may be conduits, manholes, lift stations, overflow structures, or any other component of a real system. Conduits themselves may be of different element types depending upon their geometrical cross-section (e.g., circular, rectangular, horseshoe). A sequencing is first performed (in subroutine SLOP) to order the numbered elements for computations. Flow routing then proceeds downstream through all elements during each increment in time until the storm hydrographs have been passed through the system.

An option in the program is the use of the internal storage model which acts as a transport element. The model provides the possibility of storage of the routing storm at one or two separate points within the sewer system (restricted by computer core capacity). The program routes the flow through the storage unit for each time-step based on the equation Qinflow = Qoutflow + change in storage. Entry to the internal storage subroutines is through TSTRDT (for data), TSTORG (for computations), and TSTCST (for cost).

Broad Description of Quality Routing

Contaminants are also handled by the Transport Block. Pollutants may be introduced, at the user's option, to the sewage system at three locations:

1. Storm-generated pollutographs computed by the Runoff Block are transferred on tape/disk devices to enter the system at designated inlet manholes.
2. Residual bottom sediment in the pipes may be resuspended due to the flushing action of the storm flows (subroutine DWLOAD).
3. For combined systems, DWF pollutographs (subroutine FILTH) are also entered at designated inlet manholes.

The routing of the pollutants is then done for each time-step by subroutine QUAL. The maximum number of contaminants that can be routed is four.

SUBROUTINE DESCRIPTIONS

Subroutine TRANS Ⓑ

Subroutine TRANS is the coordinating program for all quantity and quality routing in the sewer system. Most of the I/O is performed in this program, the principal exceptions being I/O to subroutines FILTH and INFIL described later. All interfacing with the Executive Block, hence with other Storm Water Management programs, is done through TRANS, and all I/O statements requiring tape/disk units are located in TRANS; some scratch tapes are also used in conjunction with subroutine PRINT. The program also performs certain functions in relation to quantity routing which will be described subsequently. A detailed flow chart of TRANS is shown in Figure 4-2.

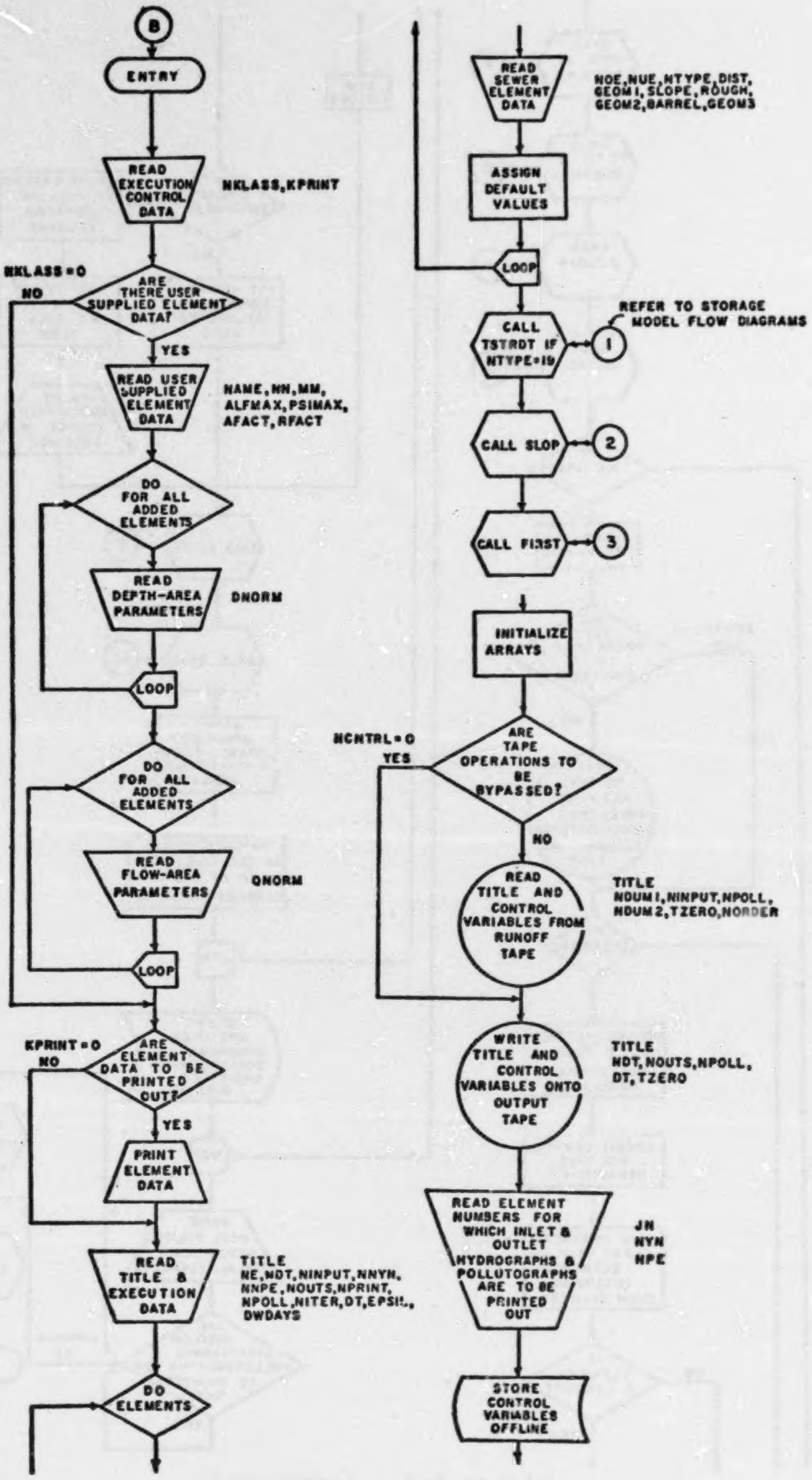

B
ENTRY
READ EXECUTION CONTROL DATA
NKLASS,KPRINT
NKLASS=0
NO
ARE THERE USER SUPPLIED ELEMENT DATA?
YES
READ USER SUPPLIED ELEMENT DATA
NAME,NN,MM,
ALFMAX,PSIMAX,
AFACT,RFACT
DO FOR ALL ADDED ELEMENTS
READ DEPTH-AREA PARAMETERS
DNORM
LOOP
DO FOR ALL ADDED ELEMENTS
READ FLOW-AREA PARAMETERS
QNORM
LOOP
KPRINT=0
NO
ARE ELEMENT DATA TO BE PRINTED OUT?
YES
PRINT ELEMENT DATA
READ TITLE & EXECUTION DATA
TITLE
NE,NDT,NINPUT,NNYN,
NNPE,NOUTS,NPRINT,
NPOLL,NITER,DT,EPSIL,
DWDAYS
DO ELEMENTS
READ SEWER ELEMENT DATA
NOE,NUE,NTYPE,DIST,
GEOM1,SLOPE,ROUGH,
GEOM2,BARREL,GEOM3
ASSIGN DEFAULT VALUES
LOOP
CALL TSTRDT IF NTYPE=19
1
REFER TO STORAGE MODEL FLOW DIAGRAMS
CALL SLOP
2
CALL FIRST
3
INITIALIZE ARRAYS
NCNTRL=0
YES
ARE TAPE OPERATIONS TO BE BYPASSED?
NO
READ TITLE AND CONTROL VARIABLES FROM RUNOFF TAPE
TITLE
NDUM1,NINPUT,NPOLL,
NDUM2,TZERO,NORDER
WRITE TITLE AND CONTROL VARIABLES ONTO OUTPUT TAPE
TITLE
NDT,NOUTS,NPOLL,
DT,TZERO
READ ELEMENT NUMBERS FOR WHICH INLET & OUTLET HYDROGRAPHS & POLLUTOGRAPHS ARE TO BE PRINTED OUT
JN
NYN
NPE
STORE CONTROL VARIABLES OFFLINE

Figure 4-2. SUBROUTINE TRANS

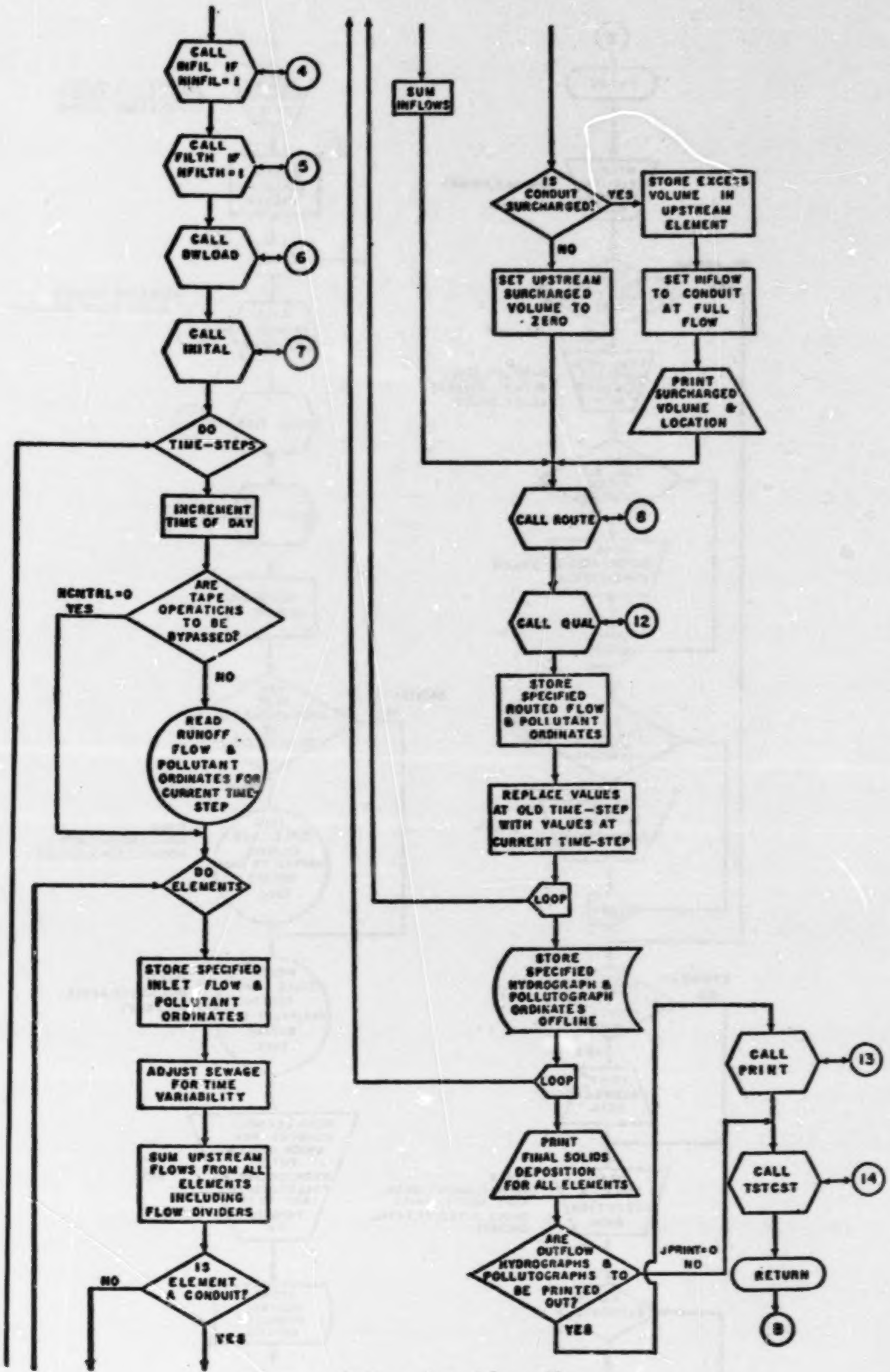

CALL INFIL IF NINFIL=1
4
CALL FILTH IF NFILTH=1
5
CALL DWLOAD
6
CALL INITAL
7
DO TIME-STEPS
INCREMENT TIME OF DAY
ARE TAPE OPERATIONS TO BE BYPASSED?
NCNTRL=0 YES
NO
READ RUNOFF FLOW & POLLUTANT ORDINATES FOR CURRENT TIME-STEP
DO ELEMENTS
STORE SPECIFIED INLET FLOW & POLLUTANT ORDINATES
ADJUST SEWAGE FOR TIME VARIABILITY
SUM UPSTREAM FLOWS FROM ALL ELEMENTS INCLUDING FLOW DIVIDERS
IS ELEMENT A CONDUIT?
NO
YES
SUM INFLOWS
IS CONDUIT SURCHARGED?
YES
NO
STORE EXCESS VOLUME IN UPSTREAM ELEMENT
SET UPSTREAM SURCHARGED VOLUME TO ZERO
SET INFLOW TO CONDUIT AT FULL FLOW
PRINT SURCHARGED VOLUME & LOCATION
CALL ROUTE
8
CALL QUAL
12
STORE SPECIFIED ROUTED FLOW & POLLUTANT ORDINATES
REPLACE VALUES AT OLD TIME-STEP WITH VALUES AT CURRENT TIME-STEP
LOOP
STORE SPECIFIED HYDROGRAPH & POLLUTOGRAPH ORDINATES OFFLINE
LOOP
PRINT FINAL SOLIDS DEPOSITION FOR ALL ELEMENTS
ARE OUTFLOW HYDROGRAPHS & POLLUTOGRAPHS TO BE PRINTED OUT?
JPRINT=0 NO
YES
CALL PRINT
13
CALL TSTCST
14
RETURN
B

Figure 4-2. (continued)

Most of the input to TRANS relates to data needed to describe the particular sewer system being modeled (e.g., dimensions, slopes, roughnesses, etc.) and parameters needed to solve the governing flow routing equations.

Following input of these data, the sewer elements are sequenced for computations in subroutine SLOP. Certain geometric and flow parameters are then initialized in subroutine FIRST while others are initialized in TRANS. The various program parameters and initialized variables describing the elements are then printed.

Element numbers at which storm hydrographs and pollutographs will enter the system are read from a tape in the order in which hydrograph and pollutograph ordinates will be read at each time-step from tapes. Parameters relating to the amount of data to be stored and printed out are also read (from cards).

If indicated, infiltration values will be calculated in subroutine INFIL and DWF quantity and quality parameters will be calculated in subroutine FILTH. Subroutine DWLOAD then initializes suspended solids deposition, and subroutine INITAL initializes flows and pollutant concentrations in each element to values corresponding to a condition of only dry weather flow and infiltration.

The main iterations of the program consist of an outer loop on time-steps and an inner loop on element numbers in order to calculate flows and concentrations in all elements at each time-step. Inlet hydrographs and pollutograph ordinates are read from a tape at each time-step prior to entering the loop on element numbers.

When in the loop on element numbers (with index I), the current sewer element through which flows are to be routed, indicated by the variable M, is determined from the vector JR(I). This array is calculated in subroutine SLOP in a manner to insure that prior to flow routing in a given element, all flows upstream will have been calculated.

When calculating flows in each element, the upstream flows are summed and added to surface runoff, DWF, and infiltration entering at that element. These latter three quantities are allowed to enter the system only at non-conduits, (e.g.,manholes, flow dividers). If the element is a conduit, a check for surcharging is made. If the inflow exceeds the conduit capacity, excess flow is stored at the element just upstream (usually a manhole) and the conduit is assumed to operate at full-flow capacity until the excess flow can be transmitted. A message indicating surcharging is printed.

Flows are then routed through each element in subroutine ROUTE and quality parameters are routed in subroutine QUAL. When routing flows in conduits, ROUTE may be entered more than once depending upon the value of ITER, the number of iterations. It is necessary to iterate upon the solution in certain cases because of the implicit nature of calculating the energy grade line in ROUTE (see description of ROUTE).

Upon completion of flow and quality routing at all time-steps for all elements, TRANS then performs the task of outputting the various data.

Hydrograph and pollutograph ordinates for the outfall point(s) are written onto tape for further use by the Executive Block, and subroutine PRINT is then called for printing outflows for any other desired elements.

Subroutine TSTRDT ①

Subroutine TSTRDT is the data input program for internal storage and is equivalent to subroutine STRDAT in the Storage Block. Basin geometry, flood level, and outlet controls must be specified. An outline flow chart of subroutine TSTRDT is shown in Figure 4-3.

Note that in order for subroutine TSTRDT to be called (from subroutine TRANS), element type 19 must be specified in one or more locations on the TRANS data cards. Presently, restrictions on machine capacity limit the maximum number of internal storage or backwater sites to 2 locations.

Subroutine SLOP ②

Subroutine SLOP orders the elements for computation so that all flows upstream of a given element will have been routed prior to flow routing in the given element. In this way routing at each time-step proceeds downstream from those elements farthest upstream.

All elements are numbered for identification, and all parameters describing a given element are read in from one data card. In the ensuing discussion, external element numbers refer to those numbers assigned to sewer elements by persons responsible for reducing the physical sewer system data. For example, the external element number assigned

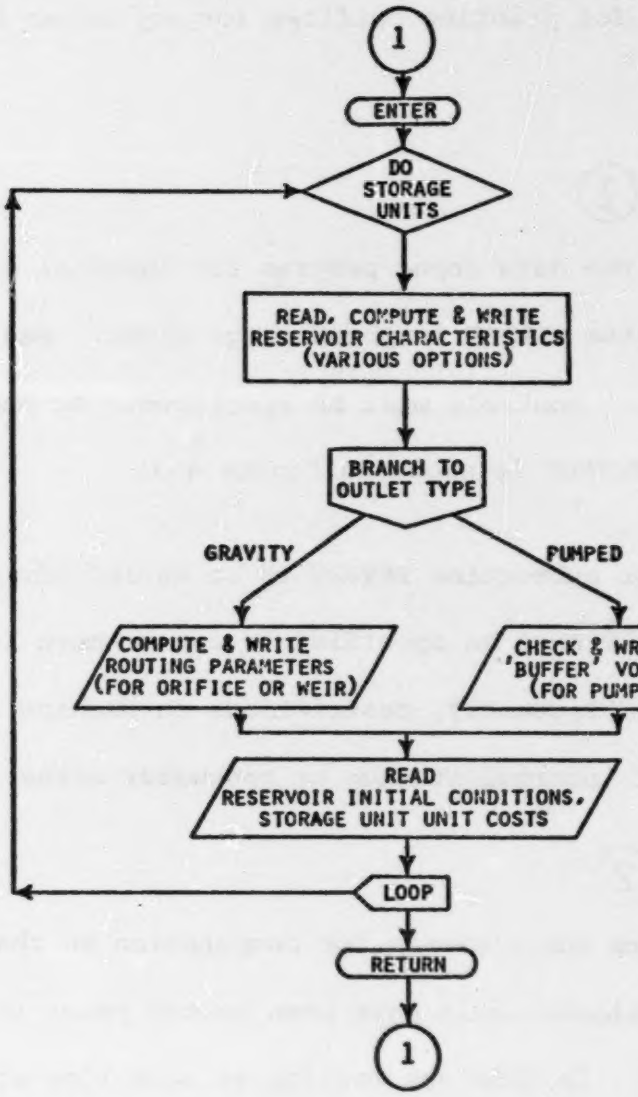

1
ENTER
DO STORAGE UNITS
READ, COMPUTE & WRITE RESERVOIR CHARACTERISTICS (VARIOUS OPTIONS)
BRANCH TO OUTLET TYPE
GRAVITY
PUMPED
COMPUTE & WRITE ROUTING PARAMETERS (FOR ORIFICE OR WEIR)
CHECK & WRITE 'BUFFER' VOLUME (FOR PUMPS)
READ RESERVOIR INITIAL CONDITIONS, STORAGE UNIT UNIT COSTS
LOOP
RETURN
1

Figure 4-3. SUBROUTINE TSTRDT

to a manhole on a map might be 213. However, due to the fact that the element data cards can be read into the computer in a random order, the internal element number is the subscript assigned to data parameters of the element by the program. For example, the card with the data for manhole number 213 may be the 49th element card read in. The internal number (subscript) associated with all data for that element will be 49.

The first task of SLOP is to determine the internal numbers of upstream elements (INUE) corresponding to the external upstream element number (NUE) entered on each data card. If an element has no elements upstream, an artificial value equal to NE+1 is assigned to the upstream element number, where NE is the total number of elements. All flows subscripted by NE+1 are subsequently assigned zero values.

After determining the internal upstream element numbers, SLOP sequences elements for computation. An element may be sequenced only after all its upstream elements have been sequenced. The vector IR indicates whether upstream elements have met this condition. When an element is found available for sequencing at step i, the internal element number is placed in the ith location of the vector JR. Thus, JR(1) contains the internal number of the element through which flows will be routed first at each time-step. JR(2) contains the number of the second element, etc.

Upon completion of the sequencing, the computation sequence and other element information is printed out. A flow chart of SLOP is shown in Figure 4-4.

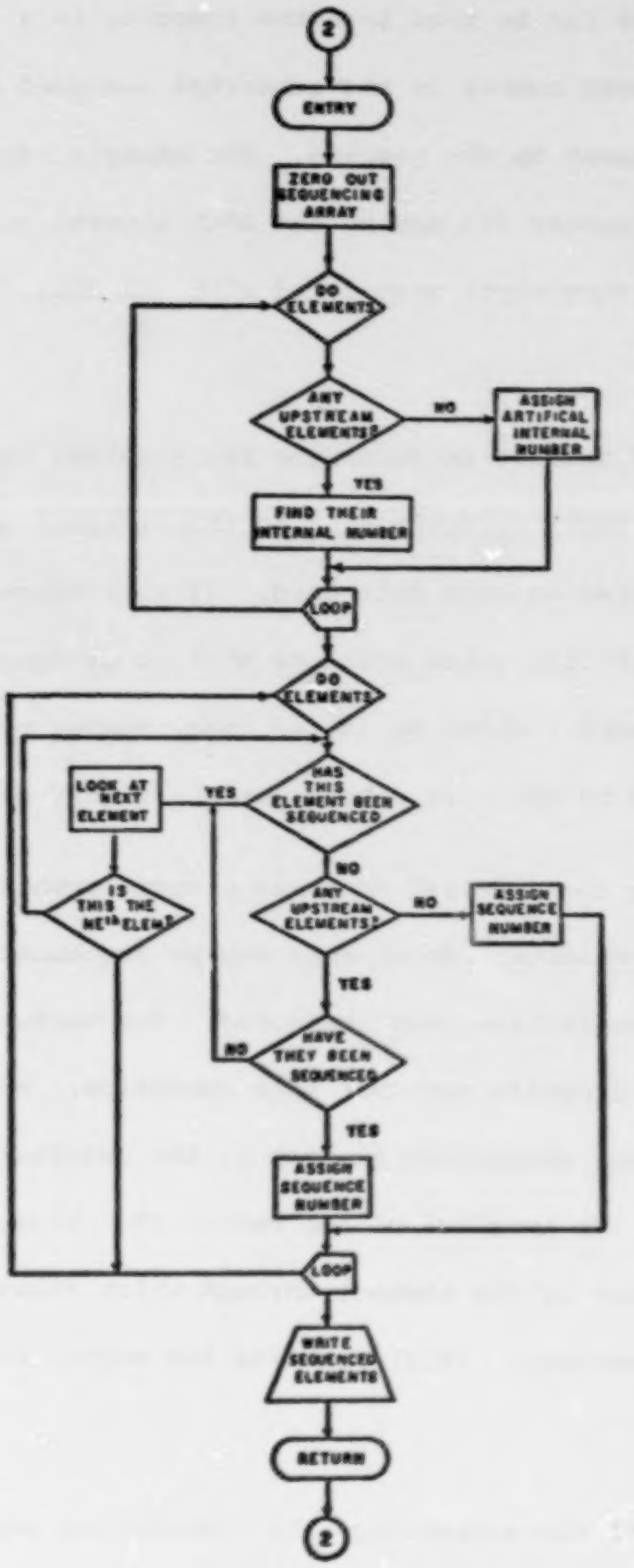

2
ENTRY
ZERO OUT SEQUENCING ARRAY
DO ELEMENTS
ANY UPSTREAM ELEMENTS?
NO
ASSIGN ARTIFICAL INTERNAL NUMBER
YES
FIND THEIR INTERNAL NUMBER
LOOP
DO ELEMENTS
LOOK AT NEXT ELEMENT
YES
HAS THIS ELEMENT BEEN SEQUENCED
NO
IS THIS THE NE^th ELEM?
ANY UPSTREAM ELEMENTS?
NO
ASSIGN SEQUENCE NUMBER
YES
NO
HAVE THEY BEEN SEQUENCED
YES
ASSIGN SEQUENCE NUMBER
LOOP
WRITE SEQUENCED ELEMENTS
RETURN
2

Figure 4-4. SUBROUTINE SLOP

Subroutine FIRST ③

Subroutine FIRST calculates parameters of each element that will remain constant throughout flow routing, such as the cross-sectional area of the conduit when flowing full (AFULL), the ratio of the conduit length to the time-step (DXDT), and other geometrical and flow parameters. Manning's equation is used in the calculation of flow parameters. Non-conduit parameters, in general, require little initialization in this subroutine. A flow chart of FIRST is shown in Figure 4-5.

Subroutine INFIL ④

The infiltration program, INFIL, has been developed to estimate infiltration into a given sewer system based upon existing information about the sewer, its surrounding soil and groundwater, and precipitation.

Using these data, INFIL has been structured to estimate average daily infiltration inflows at discrete locations along the trunk sewers of a given sewer system. A typical urban drainage basin in which infiltration might be estimated is shown in Figure 4-6.

Since the Storm Water Management Model's principal use will be to simulate individual storms which cover a time period of less than a day, average daily estimates from INFIL are calculated only once prior to sewer flow routing. INFIL is called from subroutine TRANS by setting the variable, NINFIL, equal to 1, thus signaling the computer to estimate infiltration. Figure 4-7 represents a flow chart of the subroutine.

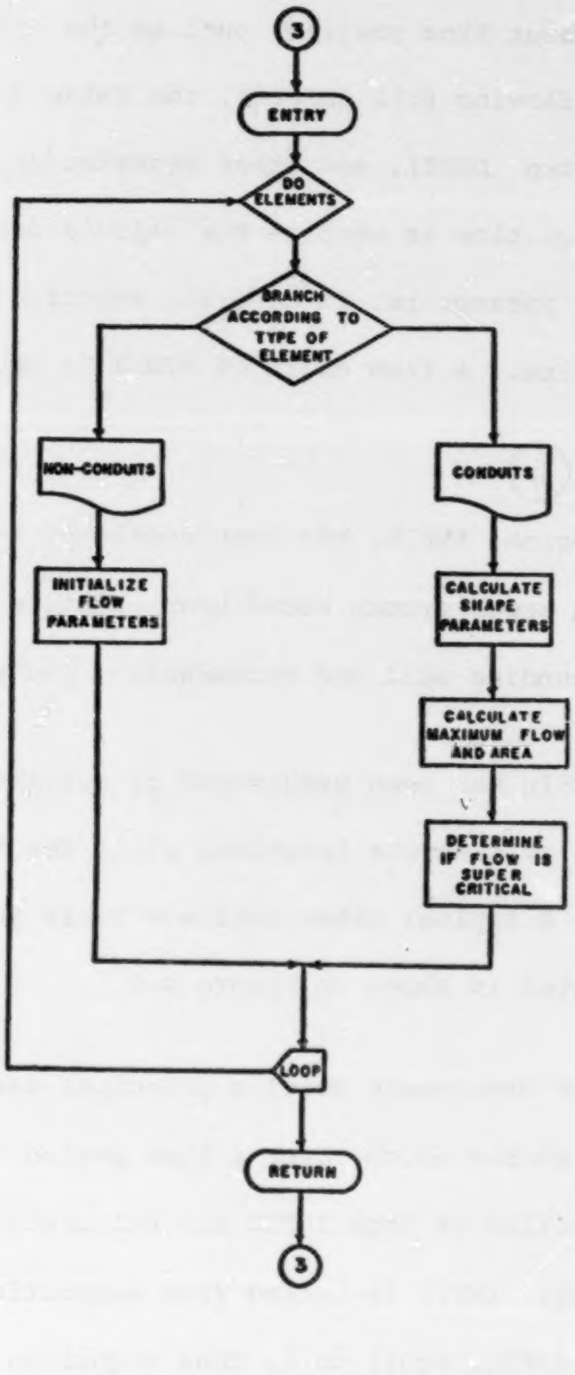

3
ENTRY
DO ELEMENTS
BRANCH ACCORDING TO TYPE OF ELEMENT
NON-CONDUITS
CONDUITS
INITIALIZE FLOW PARAMETERS
CALCULATE SHAPE PARAMETERS
CALCULATE MAXIMUM FLOW AND AREA
DETERMINE IF FLOW IS SUPER CRITICAL
LOOP
RETURN
3

Figure 4-5. SUBROUTINE FIRST

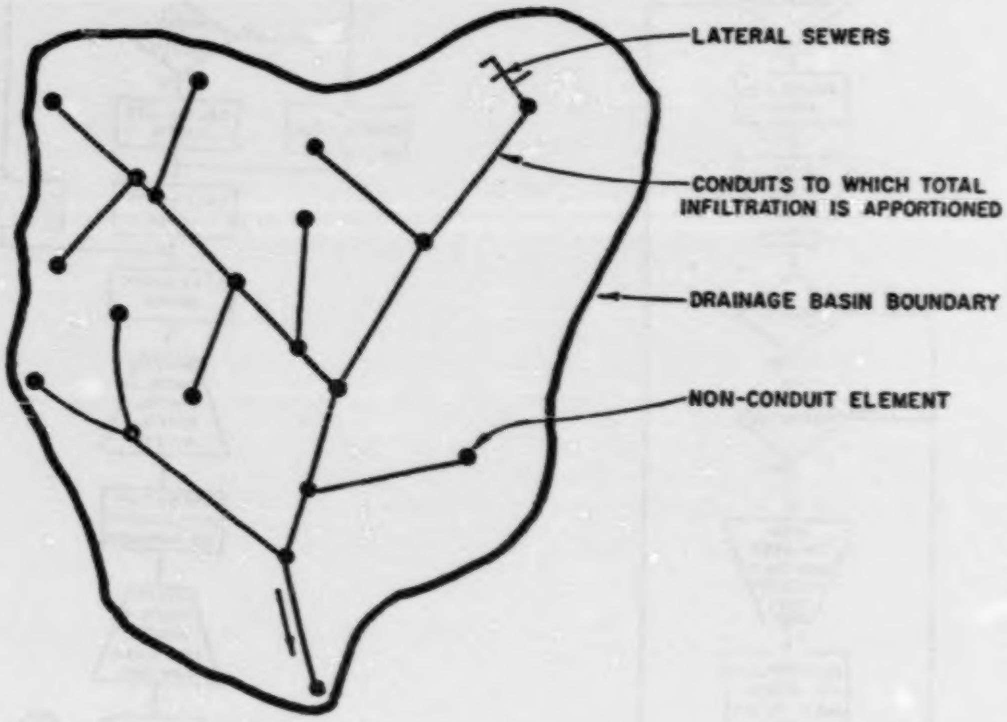

LATERAL SEWERS
CONDUITS TO WHICH TOTAL INFILTRATION IS APPORTIONED
DRAINAGE BASIN BOUNDARY
NON-CONDUIT ELEMENT

Figure 4-6. TYPICAL DRAINAGE BASIN IN WHICH INFILTRATION IS TO BE ESTIMATED

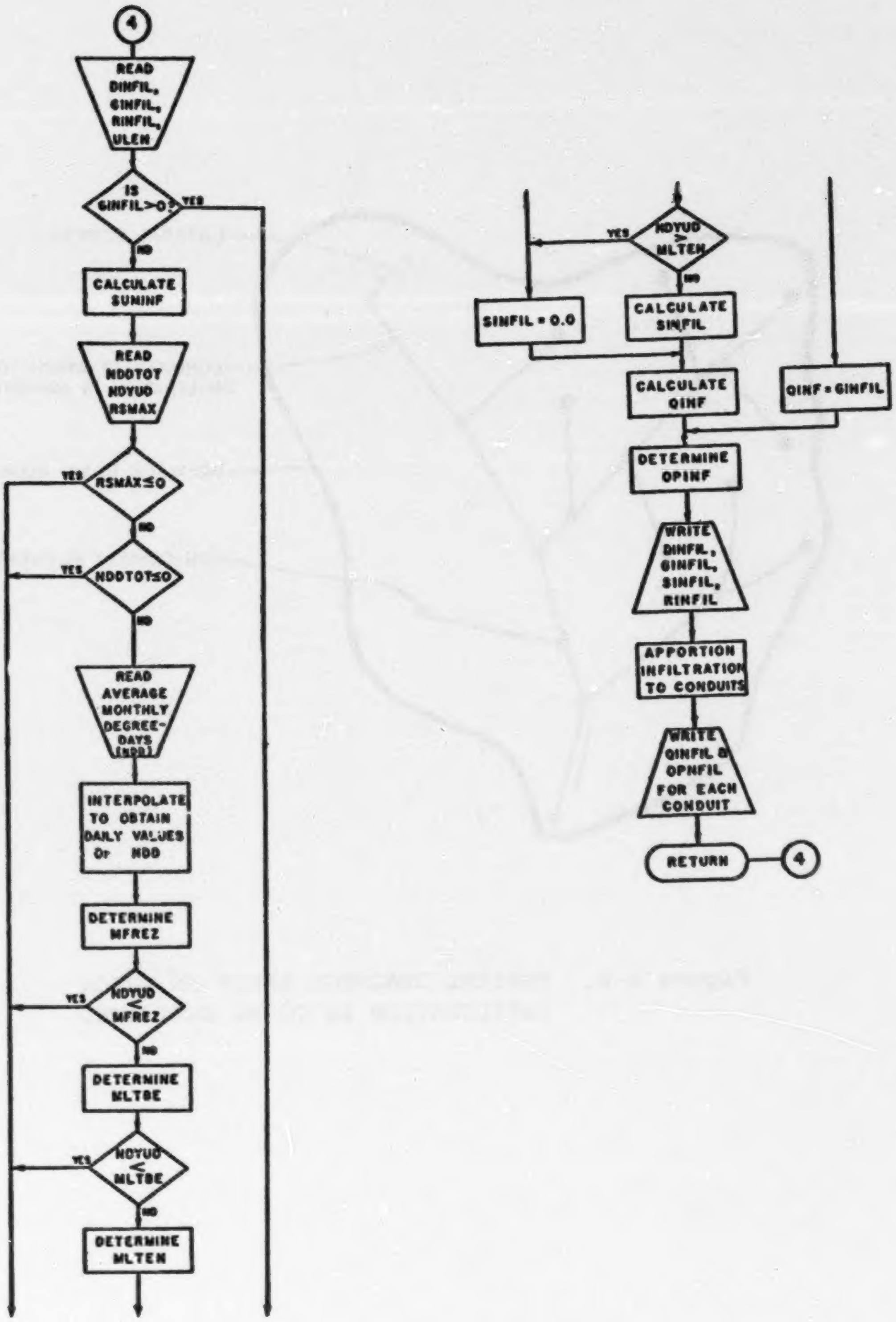

4
READ DINFIL, GINFIL, RINFIL, ULEN
IS GINFIL>0?
YES
NO
CALCULATE SUMINF
READ NDDTOT NDYUD RSMAX
RSMAX≤0
YES
NO
NDDTOT≤0
YES
NO
READ AVERAGE MONTHLY DEGREE-DAYS (NDD)
INTERPOLATE TO OBTAIN DAILY VALUES OF NDD
DETERMINE MFREZ
NDYUD < MFREZ
YES
NO
DETERMINE MLTBE
NDYUD < MLTBE
YES
NO
DETERMINE MLTEN
NDYUD > MLTEN
YES
NO
SINFIL = 0.0
CALCULATE SINFIL
CALCULATE QINF
QINF = GINFIL
DETERMINE OPINF
WRITE DINFIL, GINFIL, SINFIL, RINFIL
APPORTION INFILTRATION TO CONDUITS
WRITE QINFIL & OPNFIL FOR EACH CONDUIT
RETURN
4

Figure 4-7. SUBROUTINE INFIL

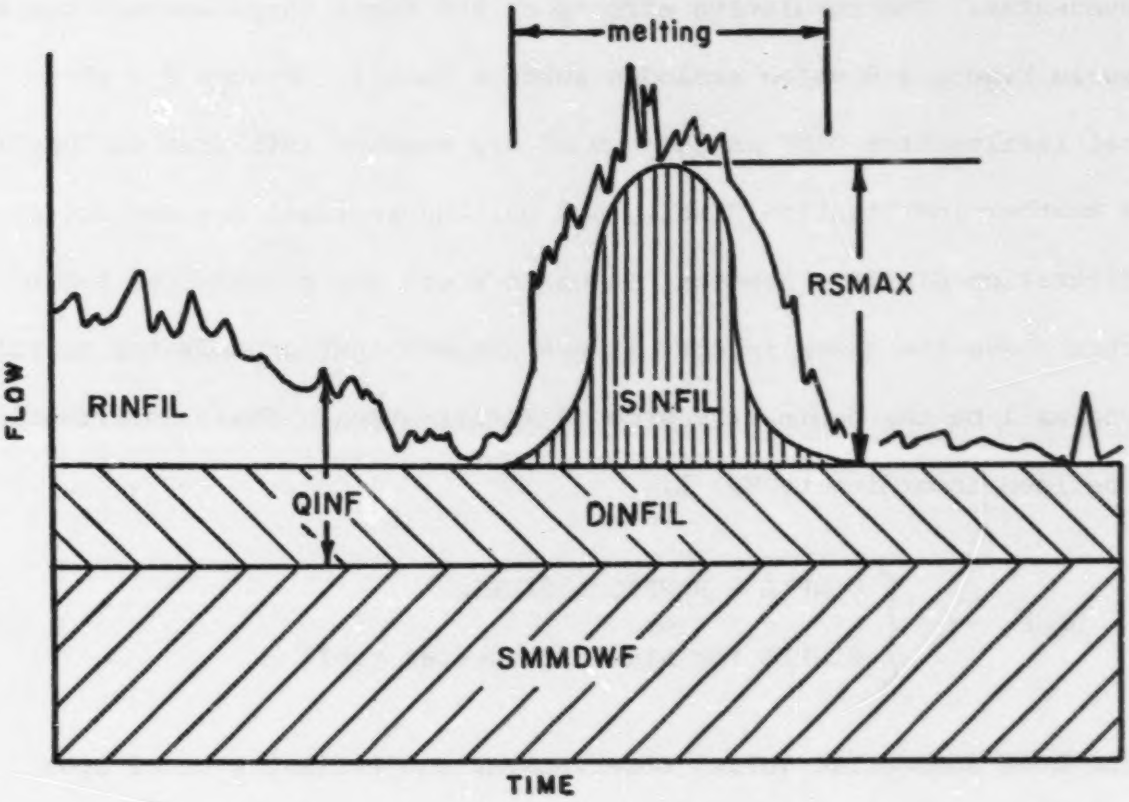
For the purposes of analysis, infiltration was classified into four categories, i.e., miscellaneous sources causing a base dry weather inflow, frozen residual moisture, antecedent precipitation, and high groundwater. The cumulative effects of the first three sources can be seen in Figure 4-8 which excludes surface runoff. Figure 4-8 shows total infiltration QINF as the sum of dry weather infiltration DINFIL, wet weather infiltration RINFIL, and melting residual ice and frost infiltration SINFIL. However, in cases where the groundwater table occurs above the sewer invert, it was assumed that groundwater GINFIL alone will be the dominant source of infiltration. Thus, infiltration is defined according to Eq. 1.

$$\text{QINF} = \begin{cases} \text{DINFIL + RINFIL + SINFIL} \\ \qquad\qquad \text{or} \\ \text{GINFIL for high groundwater table} \end{cases} \qquad (1)$$

Throughout subroutine INFIL, observations and estimates based upon local data are given preference over generalized estimates for infiltration. Thus, the hierarchy for basing estimates is as stated in the following list:

1. Use historical data for the study area under consideration.
2. Use historical data for a nearby study area and adjust results accordingly.
3. Use estimates of local professionals.
4. Use generalized estimates based upon countrywide observations.

Dry Weather Infiltration (DINFIL). If the study area under consideration has been gaged, base dry weather infiltration can be taken by



QINF = Total infiltration
DINFIL = Dry weather infiltration
RINFIL = Wet weather infiltration
SINFIL = Melting residual ice and snow infiltration
RSMAX = Residual moisture peak contribution
SMMDWF = Accounted for sewage flow

Figure 4-8. COMPONENTS OF INFILTRATION

inspection from the flow data. In the absence of flow data, an estimate of the unit infiltration rate XLOCAL (gpm/in. diam/mile) for dry weather must be obtained from local professionals. From data in the form of calculated values of DIAM and PLEN, Eq. 2 can then be used to determine DINFIL.

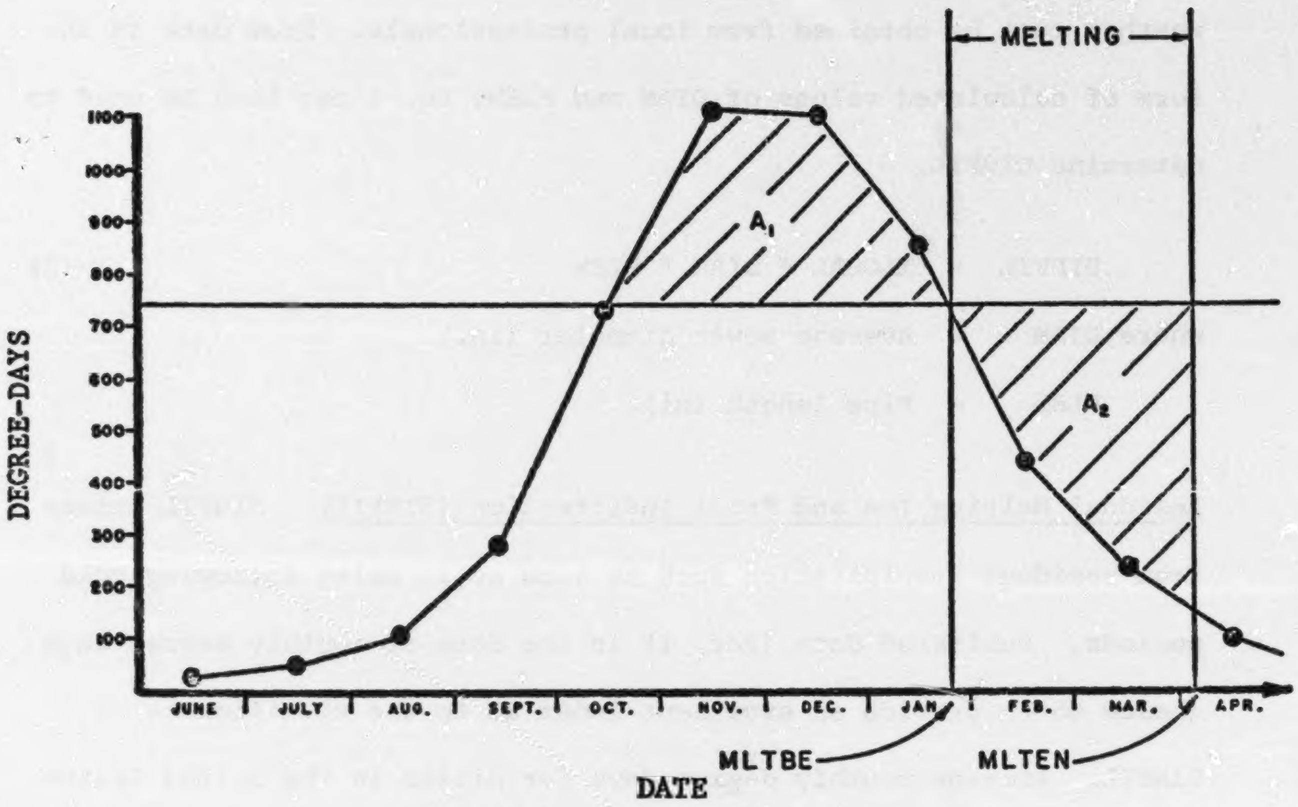
$$\mathrm{DINFIL} = \mathrm{XLOCAL} * \mathrm{DIAM} * \mathrm{PLEN} \tag{2}$$

where DIAM = Average sewer diameter (in.)

PLEN = Pipe length (mi).

Residual Melting Ice and Frost Infiltration (SINFIL). SINFIL arises from residual precipitation such as snow as it melts following cold periods. Published data (Ref. 1) in the form of monthly degree days (below 65°F) provide an excellent index as to the significance of SINFIL. Average monthly degree-days for cities in the United States are reproduced in Appendix A. The onset and duration of melting can be estimated by noting the degree days NDD above and immediately below a value of 750. Refer to Figure 4-9 for the following description.

Within subroutine INFIL, the beginning of melting MLTBE is taken as the day on which NDD drops below 750. Next, MLTEN is determined so that A_1 equals A_2. In the absence of evidence to the contrary, it is assumed that the melting rate is sinusoidal. The maximum contribution RSMAX from residual moisture can be determined from previous gaging of the study area or local estimates. In either case SINFIL is determined within the program by Eq. 3.



MLTBE = Day on which melting period begins
MLTEN = Day on which melting period ends

Figure 4-9. PRESCRIBED MELTING PERIOD

$$\mathrm{SINFIL} = \begin{cases} \mathrm{RSMAX*sin}\ \left[180*(\mathrm{NDYUD-MLTBE})/(\mathrm{MLTEN-MLTBE})\right] \\ 0.0 \text{ if NDYUD is not in melting period or if NDD never exceeds 750.} \end{cases} \qquad (3)$$

where NDYUD = Day on which infiltration estimate is desired

RSMAX = Residual moisture peak contribution (gpm)

MLTBE = Beginning of melting period (day)

MLTEN = End of melting period (day).

Antecedent Precipitation (RINFIL). RINFIL depends upon antecedent precipitation occurring within 9 days prior to an estimate. If antecedent rainfall is unavailable or less than 0.25 inch, the RINFIL contribution to QINFIL is set equal to 0.0. From analyses on reported sewer flow data not affected by melting, RINFIL was found to satisfy the following linear relationship:

$$\mathrm{RINFIL} = \mathrm{ALF} + \mathrm{ALF0} * \mathrm{RN0} + \mathrm{ALF1} * \mathrm{RN1} + \ldots + \mathrm{ALF9} * \mathrm{RN9} \qquad (4)$$

where RINFIL = SWFLOW - DINFIL - SMMDWF

ALFN = Coefficient to rainfall for N days prior to estimate

RNN = Precipitation on N days prior to estimate (in.)

SWFLOW = Daily average sewer flow excluding surface runoff (gpm)

SMMDWF = Accounted for sewage flow (gpm).

To determine the coefficients in Eq. 4, a linear regression should be run on existing flow and rainfall data. For comparative purposes, the results of regression analyses for study areas (Ref. 2) in three selected cities are given in Table 4-1.

Table 4-1. RINFIL EQUATIONS FOR THREE STUDY AREAS

Study Area		Equation
Bradenton, Florida	RINFIL =	4.1 + 2.9RN0 + 17.5RN1 + 15.0RN2 + 12.8RN3 + 13.0RN4 + 10.4RN5 + 13.2RN6 + 10.1RN7 + 11.8RN8 + 9.5RN9
Baltimore, Maryland	RINFIL =	2.4 + 11.3RN0 + 11.6RN1 + 5.5RN2 + 6.4RN3 + 4.8RN4 + 3.6RN5 + 1.0RN6 + 1.5RN7 + 1.4RN8 + 1.8RN9
Springfield, Missouri	RINFIL =	2.0 + 18.3RN0 + 13.9RN1 + 8.9RN2 + 5.5RN3 + 6.7RN4 + 16.4RN5 + 5.2RN6 + 4.6RN7 + 4.4RN8 + 1.3RN9

<u>High Groundwater Table (GINFIL)</u>. For locations and times of the year that cause the groundwater table to be above the sewer invert, groundwater infiltration GINFIL supersedes any notations of DINFIL, RINFIL, and SINFIL. GINFIL can be determined from historical sewer flow data by inspection or regression analysis. Regression analysis would involve determineation of the BETA coefficients in Eq. 5.

```
GINFIL = BETA + BETA1 * GWHD + BETA2*GWHD**2 + BETA3 * GWHD**0.5   (5)
```

where GWHD = Groundwater table elevation above sewer invert (ft)

BETAN = Coefficient for term N in Eq. 5.

<u>Apportionment of Infiltration</u>. Once an estimate of local infiltration QINF has been obtained, this flow must be apportioned throughout the designated study area. The criterion chosen for apportionment is an opportunity factor OPINF which represents the relative number and length of openings susceptible to infiltration. Pipe joints constitute the primary avenue for entry of infiltration (Ref. 3).

OPINF for an entire study area is determined within INFIL using Eq. 6:

$$\mathrm{OPINF} = \sum_{\text{conduits}} (\pi * \mathrm{DIAM} * \mathrm{DIST/ULEN}) \tag{6}$$

where π * DIAM = Pipe circumference (ft)

DIST/ULEN = Number of joints in each conduit

ULEN = Average distance between joints.

Hydrologic Data. Concurrent historical rainfall, water table, and sewer flow data of several weeks' duration are needed to completely describe infiltration. In addition, rainfall for the 9 days prior to the flow estimate is required to satisfy the regression equation for RINFIL.

Ideally, the rainfall record would be from a rain gage which is located near the center of the study area and which records daily rainfall in inches. If more than one rain gage is located within the study area, daily measurements from all gages should be averaged. Missing data (e.g., from a malfunctioning gage) or a total absence of measurements due to no gaging within the study area can be overcome with measurements taken from a rain gage located within a few miles. If Weather Bureau Climatological Data recorded at the nearest airport or federal installation are not available, contact the National Weather Bureau Records Center for assistance (Ref. 4).

Should some other form of precipitation, e.g., snowfall, be encountered, it will be necessary to convert this to equivalent rainfall. If estimates are unavailable from the Weather Bureau, the ratio of 10 inches of snow to 1 inch of rain may be used.

Water table data should also be obtained from gaging within the study area. However, shallow-well data from the U. S. Geological Survey or state geological office can be used to supplement missing data. Water table elevations are not required if they are below the sewer inverts for the day on which QINF is to be estimated.

Sewer Data. Sewer flow data for regression analysis should be taken from a gage located at the downstream point within the study area. Upstream gaging may be used to estimate flows at the downstream point by simply adjusting flows based upon respective surface area.

Physical sewer data (e.g., lengths, diameters, shapes) are taken from information used within TRANS to route sewer flow. To assist in determining the number of joints in the trunk sewer, an estimate of the average pipe section length ULEN should be supplied.

Subroutine FILTH ⑤

Subroutine FILTH has been developed to estimate average sewage flow and quality from residential, commercial, and industrial urban areas. FILTH estimates sewage inputs at discrete locations along the trunk sewers of any specified urban drainage basin. These estimates are calculated from data describing drainage basin subsections (subcatchments and subareas) under which the trunk sewer passes. An example of a hypothetical sewer system and input situation is given in Figure 4-10. To save repetition all drainage basin subdivisions will be referred to

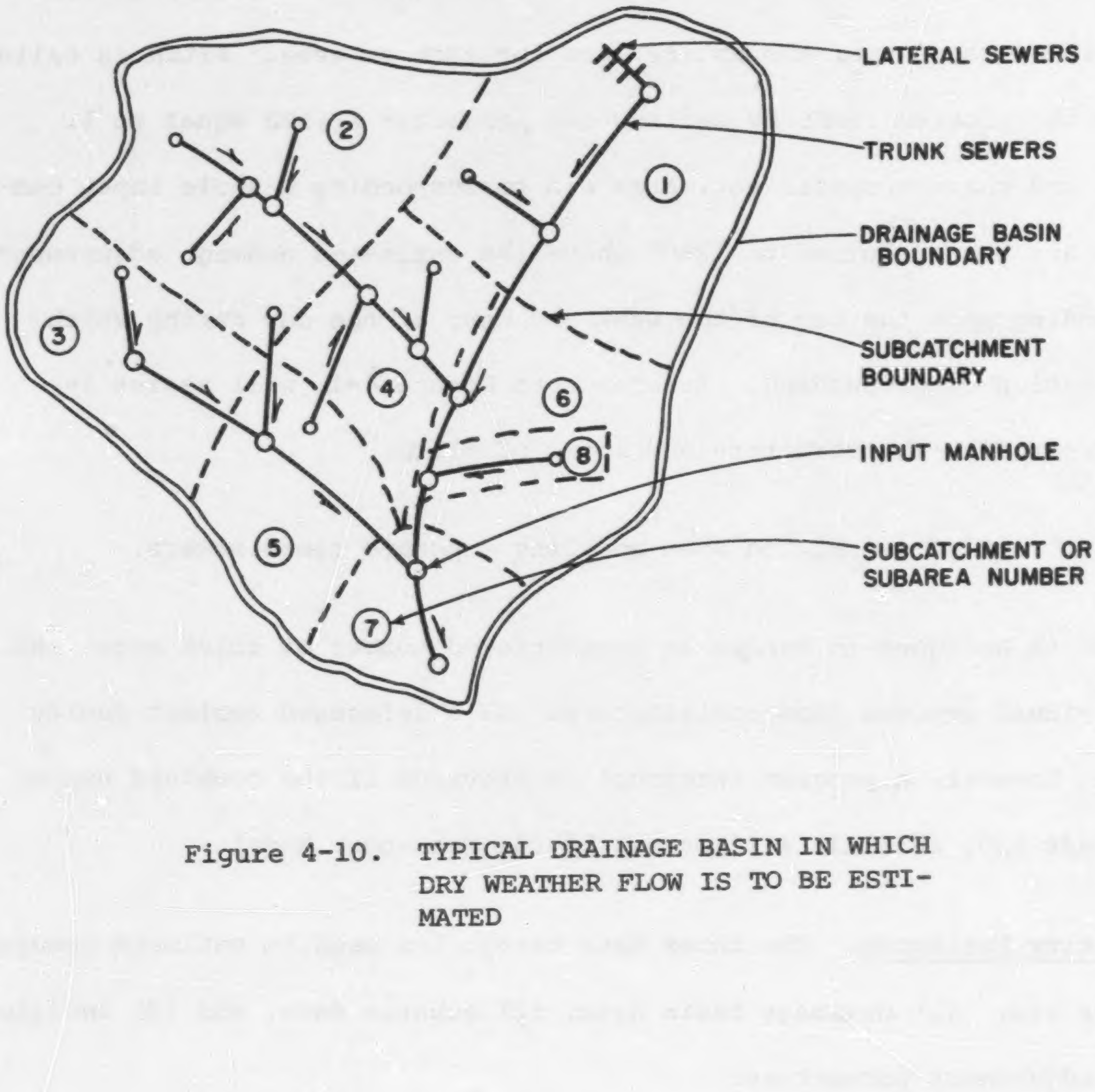

LATERAL SEWERS
TRUNK SEWERS
DRAINAGE BASIN BOUNDARY
SUBCATCHMENT BOUNDARY
INPUT MANHOLE
SUBCATCHMENT OR SUBAREA NUMBER
1
2
3
4
5
6
7
8

Figure 4-10. TYPICAL DRAINAGE BASIN IN WHICH DRY WEATHER FLOW IS TO BE ESTIMATED

as subareas in the following discussion. As shown in the figure, an input manhole near the center of each subarea is assumed to accept all sewage flow from that subarea. Criteria for establishing subarea boundaries and input locations are discussed later in the text.

In the context of the Storm Water Management Model, FILTH calculates daily sewage flow (cfs) and characteristics (BOD, SS, and total coliforms) averaged over the entire year for each subarea. FILTH is called from the program TRANS by setting the parameter NFILTH equal to 1. Flow and characteristic estimates and corresponding manhole input numbers are then returned to TRANS where the estimates undergo adjustment depending upon the day of the week and hour of the day during which simulation is proceeding. Reference to Figure 4-11 will assist in understanding the structure and logic of FILTH.

The subroutine is omitted when modeling separate storm sewers.

FILTH is designed to handle an unrestricted number of inlet areas and individual process flow contributors. As a safeguard against faulty data, however, a program interrupt is provided if the combined number exceeds 150, which is a limit set by the Transport Model.

Quantity Estimates. The three data categories used to estimate sewage flows are: (1) drainage basin data, (2) subarea data, and (3) decision and adjustment parameters.

Study area data are TOTA, KTNUM and ADWF. KTNUM denotes the number of subareas into which a drainage basin, having a surface area TOTA (acres),

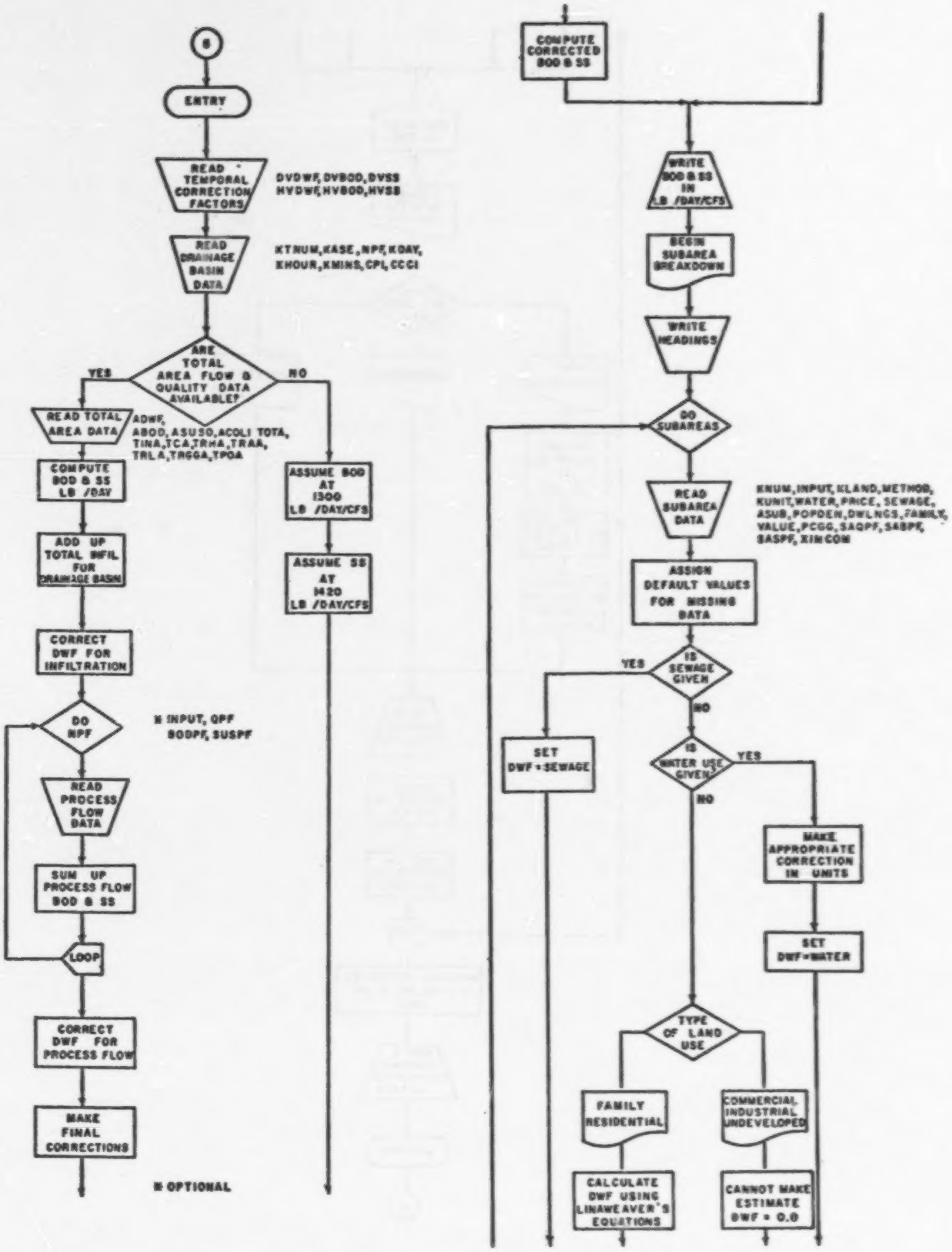

ENTRY
READ TEMPORAL CORRECTION FACTORS
DVDWF, DVBOD, DVSS
HVDWF, HVBOD, HVSS
READ DRAINAGE BASIN DATA
KTNUM, KASE, NPF, KDAY,
KHOUR, KMINS, CPI, CCCI
ARE TOTAL AREA FLOW & QUALITY DATA AVAILABLE?
YES
NO
READ TOTAL AREA DATA
ADWF,
ABOD, ASUSO, ACOLI TOTA,
TINA, TCA, TRHA, TRAA,
TRLA, TRGGA, TPOA
COMPUTE BOD & SS LB /DAY
ASSUME BOD AT 1300 LB /DAY/CFS
ASSUME SS AT 1420 LB /DAY/CFS
ADD UP TOTAL INFIL FOR DRAINAGE BASIN
CORRECT DWF FOR INFILTRATION
DO NPF
* INPUT, QPF
BODPF, SUSPF
READ PROCESS FLOW DATA
SUM UP PROCESS FLOW BOD & SS
LOOP
CORRECT DWF FOR PROCESS FLOW
MAKE FINAL CORRECTIONS
* OPTIONAL
COMPUTE CORRECTED BOD & SS
WRITE BOD & SS IN LB /DAY/CFS
BEGIN SUBAREA BREAKDOWN
WRITE HEADINGS
DO SUBAREAS
READ SUBAREA DATA
KNUM, INPUT, KLAND, METHOD,
KUNIT, WATER, PRICE, SEWAGE,
ASUB, POPDEN, DWLNGS, FAMILY,
VALUE, PCGG, SAQPF, SABPF,
SASPF, XINCOM
ASSIGN DEFAULT VALUES FOR MISSING DATA
IS SEWAGE GIVEN
YES
NO
SET DWF = SEWAGE
IS WATER USE GIVEN?
YES
NO
MAKE APPROPRIATE CORRECTION IN UNITS
SET DWF = WATER
TYPE OF LAND USE
FAMILY RESIDENTIAL
COMMERCIAL INDUSTRIAL UNDEVELOPED
CALCULATE DWF USING LINAWEAVER'S EQUATIONS
CANNOT MAKE ESTIMATE DWF = 0.0

Figure 4-11. SUBROUTINE FILTH

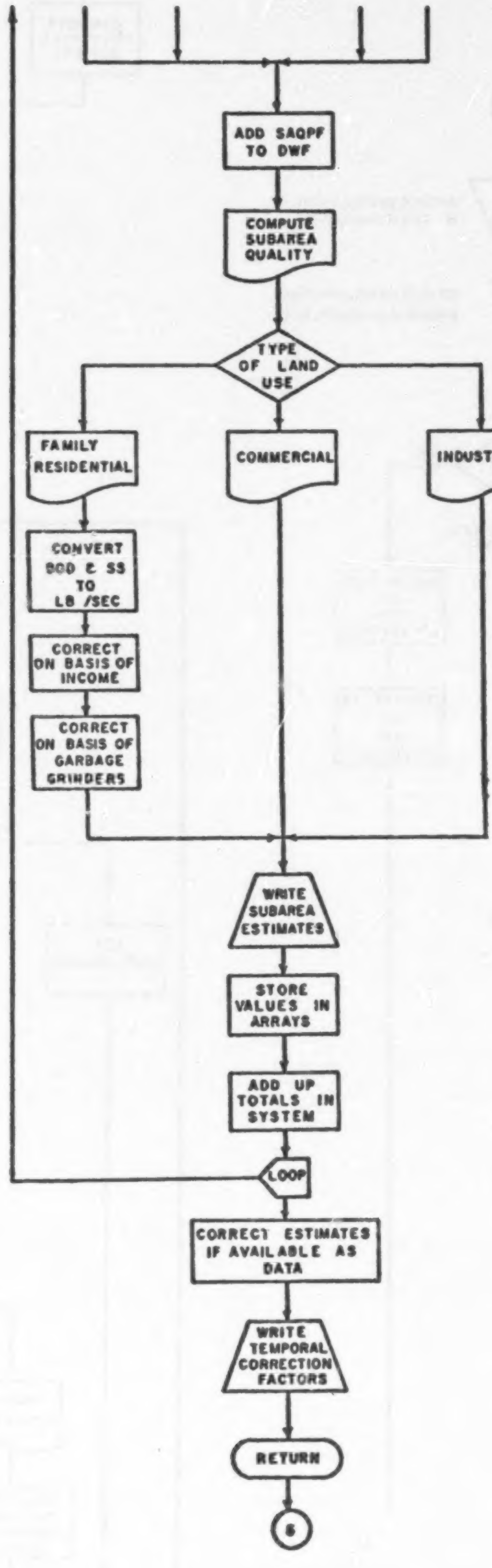

ADD SAQPF TO DWF
COMPUTE SUBAREA QUALITY
TYPE OF LAND USE
FAMILY RESIDENTIAL
COMMERCIAL
INDUSTRIAL
CONVERT BOD & SS TO LB /SEC
CORRECT ON BASIS OF INCOME
CORRECT ON BASIS OF GARBAGE GRINDERS
WRITE SUBAREA ESTIMATES
STORE VALUES IN ARRAYS
ADD UP TOTALS IN SYSTEM
LOOP
CORRECT ESTIMATES IF AVAILABLE AS DATA
WRITE TEMPORAL CORRECTION FACTORS
RETURN
6

Figure 4-11. (continued)

is being divided. ADWF, which is optional depending upon its availability, gives the average sewage flow (cfs) originating from the entire drainage basin (e.g., average flow data from a treatment plant serving the study area).

Subarea data requirements consist of several options depending upon availability and choice of input. Discussion later in the text will assist in data tabulation by noting the order of preference where options exist. Subarea data can be broken into three categories as follows: (1) identification parameters, (2) flow data, and (3) estimating data.

1. Identification Parameters

Identification parameters are KNUM, INPUT, and KLAND. KNUM identifies each subarea by a number less than or equal to KTNUM. For each of the KTNUM subareas, INPUT indicates the number of the manhole into which DWF is assumed to enter. Land use within each subarea which approximately corresponds to zoning classification, is categorized according to Table 4-2. KLAND serves as an important factor in deciding subarea locations and sizes. Figure 4-12 will assist in describing how the above data are determined and tabulated.

2. Flow Data

Flow data are optional inputs that eliminate the need for using predictive equations. Two possible types of flow data are average sewage flow measurements, SEWAGE, and metered water use, WATER. Commercial or industrial sewage flow or

Table 4-2. LAND USE CLASSIFICATION

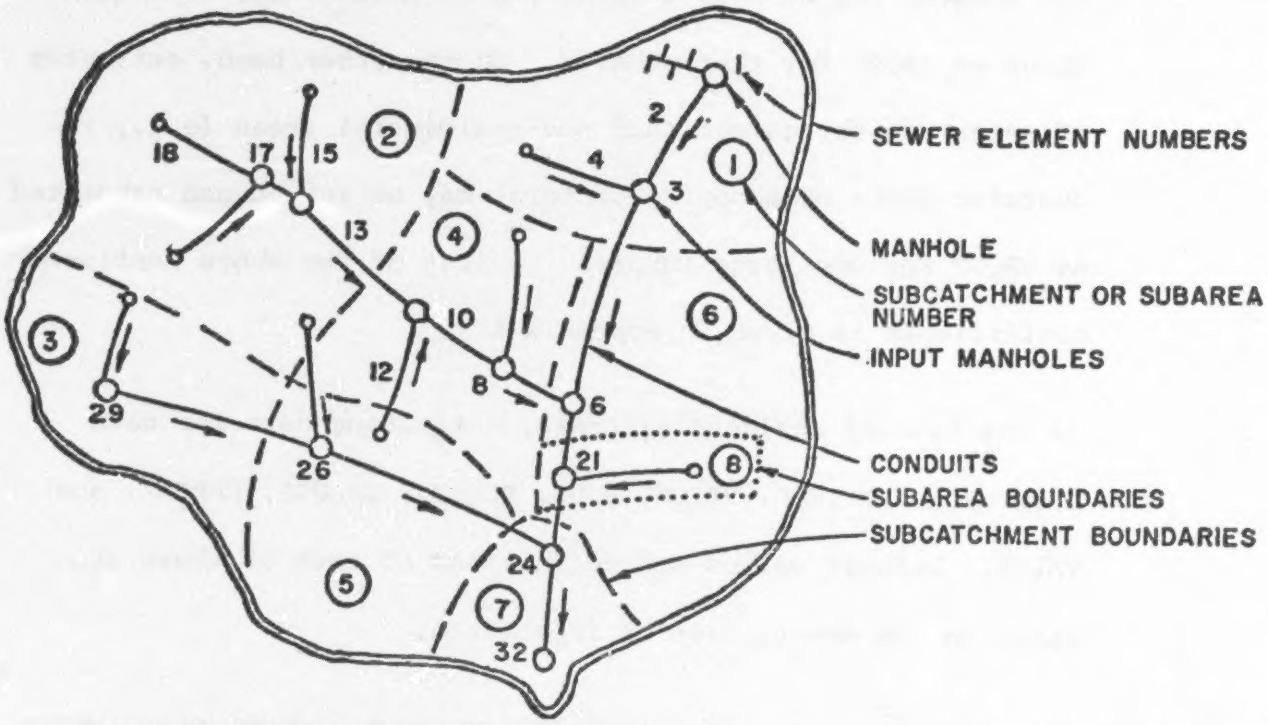
KLAND	
1	Single-family residential
2	Multi-family residential
3	Commercial
4	Industrial
5	Park and open area

water use measurements should be input using the variable SAQPF. Flows from commercial and industrial establishments located in residential subareas may be included using SAQPF, also.

Metering at lift stations and other flow control structures within the study area is occasionally available and should be used whenever possible. Metered water use offers a more available source of subarea flow data. Unfortunately, considerable effort in locating, tabulating, and averaging these data is often required.

3. Estimating Data

For each subarea where SEWAGE and WATER measurements are not available, estimated water use must be used as an estimate of sewage flow. In the case of a factory or commercial establishment, estimates can be made by multiplying the number of employees by an established coefficient (gpd per employee). In the case of a large factory or commercial establishment,


1
2
18
17
15
2
4
3
1
13
4
10
6
3
12
8
6
29
26
21
8
24
5
7
32
SEWER ELEMENT NUMBERS
MANHOLE
SUBCATCHMENT OR SUBAREA NUMBER
INPUT MANHOLES
CONDUITS
SUBAREA BOUNDARIES
SUBCATCHMENT BOUNDARIES

Sewer and Subcatchment Data

1. Manhole 32 is the most downstream point.
2. Subcatchments 1,2,3, and 4 are single-family residential areas, each 100 acres in size and each with water metering.
3. Subcatchments 5 and 7 are 220-acre industrial areas.
4. Subarea 6 is a 250-acre park.
5. Subarea 8 is a 50-acre commercial area.

Subareas 6 and 8 constitute a subcatchment draining to input manhole number 21.

Resulting Data

8 sewage estimates
KTNUM, total subcatchments and subareas in drainage basin = 8.
TOTA, total acres in drainage basin = 1,140.

KNUM, subcatchment or subarea	INPUT, input manhole number	KLAND, land use category	ASUB, acres in subcatchment or subarea
1	3	1	100
2	17	1	100
3	29	1	100
4	8	1	100
5	26	4	220
6	21	5	250
7	24	4	220
8	21	3	50

Figure 4-12. DETERMINATION OF SUBCATCHMENT AND IDENTIFICATION DATA TO ESTIMATE SEWAGE AT 8 POINTS

one subarea may be established with estimated water use tabulated as SAQPF for that subarea. On the other hand, estimates of water use for established non-residential areas (e.g., industrial parks or shopping centers) may be summed and tabulated as SAQPF for one large subarea. A list of the above mentioned coefficients is given in Appendix A.

In the case of residential areas, estimating data for each subarea are METHOD, PRICE, ASUB, POPDEN, DWLNGS, FAMILY, and VALUE. Default values and definitions of each of these are given in the description of input data.

Decision and adjustment parameters consist of DVDWF, HVDWF, KDAY, KHOUR, KMINS, CPI, and CCCI. DVDWF and HVDWF are daily and hourly correction factors, respectively, for DWF. DVDWF is comprised of 7 numbers that are ratios of daily average sewage flows to weekly average flow. Likewise, HVDWF is comprised of 24 numbers that are ratios of hourly average sewage flows to daily average flow. Both groups of numbers have been derived from observed flow variation patterns throughout the country (Refs. 5, 6). Their use is to correct measured or estimated average sewage flow to more accurate estimates depending upon the day and hour. Typical sewage flow variations are shown in Figures 4-13 and 4-14. Even though these flow patterns are suggested, locally observed patterns more accurately describe local variations and should be used when available.

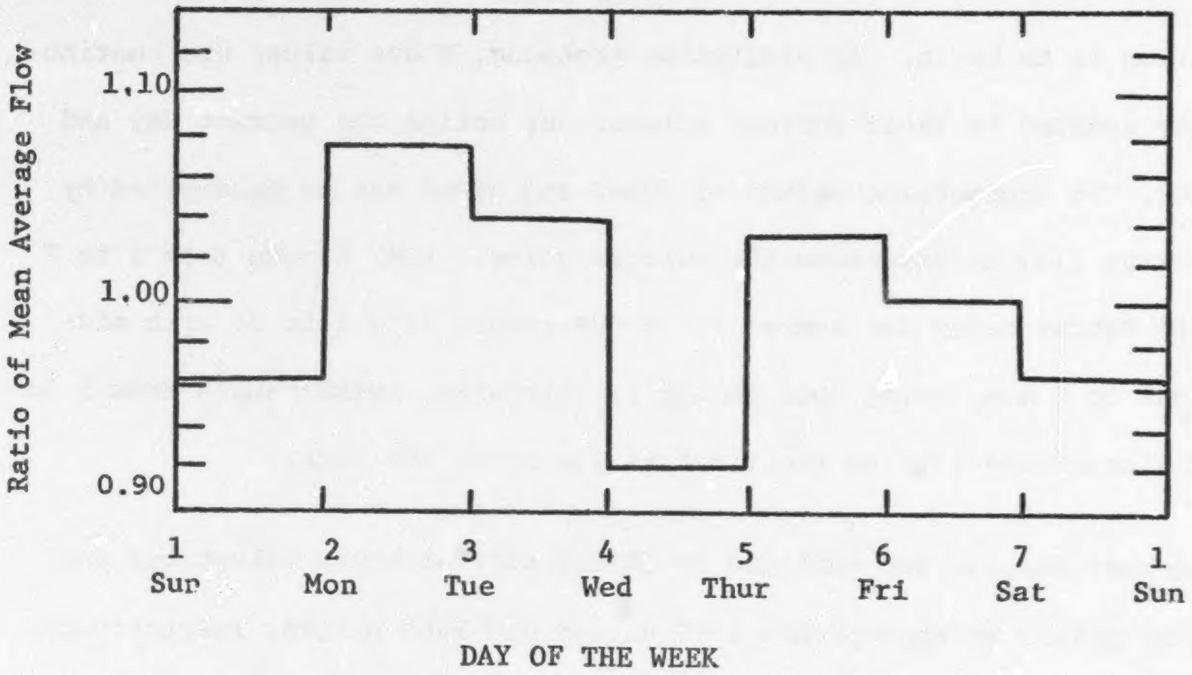


Figure 4-13. REPRESENTATIVE DAILY FLOW VARIATION

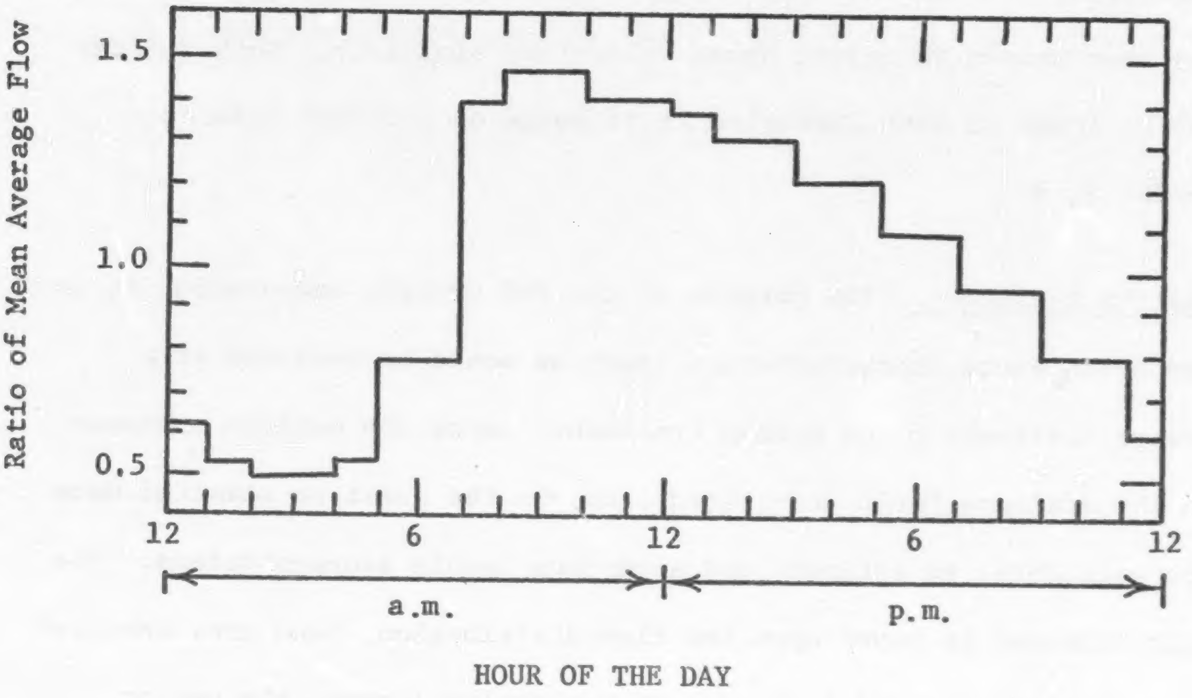


Figure 4-14. REPRESENTATIVE HOURLY FLOW VARIATION

KDAY, KHOUR, and KMINS denote the day, hour, and minute at which simulation is to begin. As simulation proceeds, these values are continually updated to their correct values. By noting the current day and hour, the appropriate values of DVDWF and HVDWF can be multiplied by average flow to determine the correct value. KDAY ranges from 1 to 7 with Sunday being day number 1. KHOUR ranges from 1 to 24 with midnight to 1 a.m. being hour number 1. Likewise, KMINS ranges from 1 to 60 with minute 1 being the first minute after the hour.

Two cost indices are employed to adjust current house valuations and water prices to appropriate 1960 values and 1963 prices, respectively. This is done because estimating equations within FILTH are based upon 1960 values and 1963 prices. CPI, consumer price index, has been chosen to adjust water price by multiplying water price by 1960 CPI divided by the current CPI. CCCI, composite construction cost index, has been chosen to adjust house valuations similarly. Both indices can be found in most libraries in journals on economic affairs (Refs. 7, 8).

Quality Estimates. The purpose of the DWF quality computation is to apportion waste characteristics (such as would be measured at a sewage treatment plant before treatment) among the various subareas in the drainage basin under study, or, in the event no measured data are available, to estimate and apportion usable average values. The apportionment is based upon the flow distribution, land use, measured or estimated industrial flows, average family income, the use or absence of garbage grinders, and infiltration. A generalized flow diagram showing the interrelationships with the quantity computations is shown in Figure 4-11.

When called, subroutine FILTH first reads in an array of daily and hourly flow and characteristic variations. All are expressed as ratios of their respective yearly or daily averages and they are stored in real time sequence (one set of values for each day starting with Sunday or each hour starting at 1:00 a.m.).

The next card read gives the total number of subareas and process flow sources to be processed; the type case--that is, whether the total DWF characteristics are known or to be estimated; the number of process flow contributors; the starting time of the storm event; the cost indices; and the total drainage basin population.

The next series of computations sets values for A1BOD, A1SS, and A1COLI, which are the average weighted DWF characteristics in lb/day/cfs for BOD and SS and in MPN/day/capita for total coliforms. Depending upon the instructions given, computations proceed along Case 1 or Case 2 channels.

Case 1

In this instance the total DWF quality characteristics are known at a point well downstream in the system. These characteristics may be obtained from treatment plant operating records (raw sewage) or by a direct sampling program. The average daily values are read into the program for flow, BOD, SS, and coliforms. The total pounds per day of BOD and SS and the total MPN per day of coliforms are then calculated. Then, infiltration is subtracted from the average daily flow. (Note that infiltration is computed by a separate subroutine of the Transport Model and must be executed prior to subroutine FILTH or a default value will be assumed.)

Next, the known process flow contributions are summed and deducted from the daily totals, yielding a further corrected flow, C2DWF, and characteristics, C1BOD and C1SS.

Finally, corrections are made for personal income variations, degree of commercial use, and garbage grinder status. The DWF quantity does not change but the characteristics obtain new, weighted values, C2BOD and C2SS.

A1BOD and A1SS are then computed directly. A1COLI is computed by dividing the total MPN per day by the total population.

Case 2

Here no direct measurements are available; thus, estimates must be made or default values will be assumed. A typical application of Case 2 would be in a situation where several catchments are to be modeled, yet funds will permit monitoring the DWF only in a single area. A1BOD, A1SS, and A1COLI would be computed via the Case 1 subroutine for the known area and the results would be transferred as Case 2 for the remaining catchments.

The default values for A1BOD, A1SS, and A1COLI are 1,300, 1,420, and 200 billion respectively. These values assume 85 gal./capita/day, 0.20 lb/capita/day BOD, 0.22 lb/capita/day SS, and 200 billion MPN/capita/day for average income families.

A loop is next formed to compute and design average daily quality values for all inlets and individual process flow sources. This loop also computes the DWF quantities as described earlier.

Two data cards are required to read in all the flow and quality parameters for each subarea and each individual process flow source. After computation of the DWF quantity for the subarea, the population is computed and totalized. Next, the quality characteristics are computed on the basis of land use, family income, and garbage grinder status, and the results are tabulated (printed) and totalized (printed only on call - subtotals - or completion).

The computational sequence is complete when all areas and process flow sources have been executed (i.e., number of iterations equals KTNUM) and totals have been printed. Upon completion, control returns to TRANS.

Subroutine DWLOAD ⑥

Subroutine DWLOAD was developed to assist subroutine QUAL (which will be discussed later) by establishing the initial sediment load within a sewer system. This was accomplished by using Shield's and Manning's works to estimate daily sediment accumulation in each section of the sewer under DWF conditions. By assuming a constant daily buildup of sediment during consecutive dry weather days, DWDAYS, initial sediment load estimates were made possible. Thus, a substantial portion of the solids that might contribute to a first flush of the sewers was allowed. Refer to Figure 4-15 for further description of DWLOAD.

Program usage of DWLOAD is quite simple, as DWDAYS, the number of days since the last storm that caused cleansing of the sewer, is the only data input. This number must be included with the data for TRANS.

Subroutine INITAL ⑦

Combined sewer systems will seldom if ever be dry because of their dual function of carrying DWF as well as storm flow. In the case of a storm sewer, DWF will consist of only infiltration. Subroutine INITAL thus initializes flows in the system to the appropriate DWF values. Pollutant concentrations are initialized to those corresponding to wastewater diluted by infiltration, which is assumed to contain no pollutants.

Flow areas in conduits are determined from Manning's equation assuming normal depths initially. A flow chart of INITAL is shown in Figure 4-16.

Subroutine ROUTE ⑧

Subroutine ROUTE contains the fundamental aspects of flow routing through all elements. Upon entering ROUTE, a check is made to determine if the element is a conduit or not, using the variable KLASS.

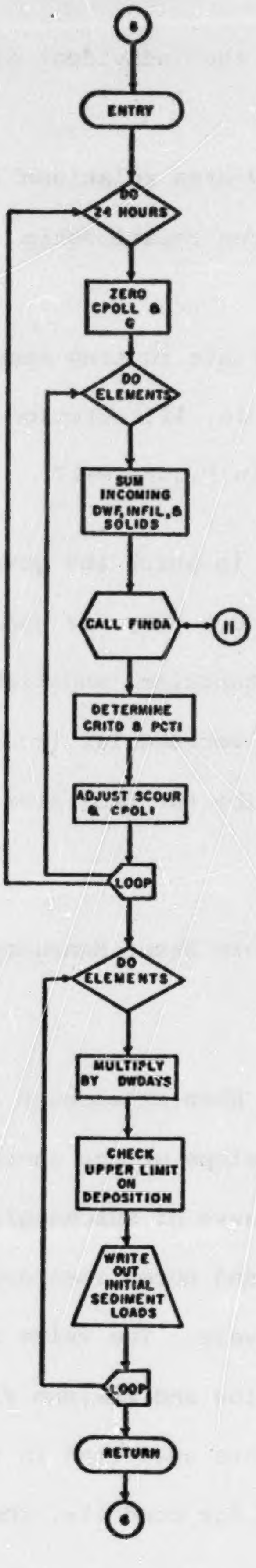

6
ENTRY
DO 24 HOURS
ZERO CPOLL & G
DO ELEMENTS
SUM INCOMING DWF, INFIL, & SOLIDS
CALL FINDA
11
DETERMINE CRITD & PCTI
ADJUST SCOUR & CPOLI
LOOP
DO ELEMENTS
MULTIPLY BY DWDAYS
CHECK UPPER LIMIT ON DEPOSITION
WRITE OUT INITIAL SEDIMENT LOADS
LOOP
RETURN
6

Figure 4-15. SUBROUTINE DWLOAD

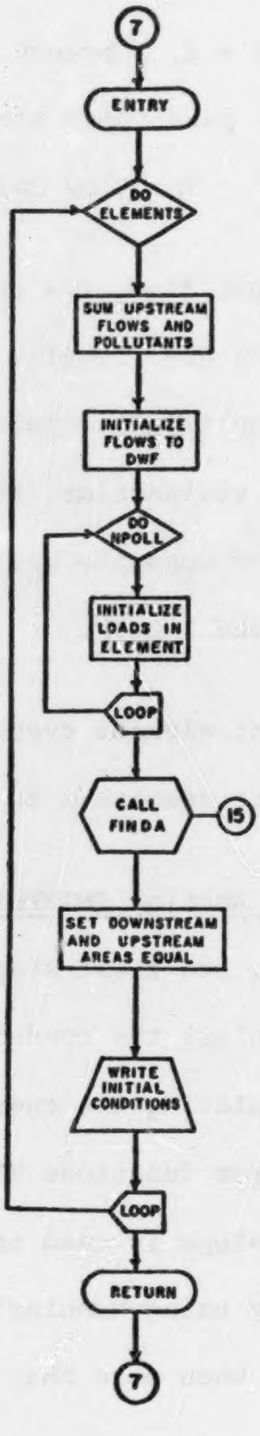

7
ENTRY
DO ELEMENTS
SUM UPSTREAM FLOWS AND POLLUTANTS
INITIALIZE FLOWS TO DWF
DO NPOLL
INITIALIZE LOADS IN ELEMENT
LOOP
CALL FINDA
15
SET DOWNSTREAM AND UPSTREAM AREAS EQUAL
WRITE INITIAL CONDITIONS
LOOP
RETURN
7

Figure 4-16. SUBROUTINE INITAL

KLASS is a function of the element type (not the individual element number) and has the following values:

KLASS = 1 Conduit with a functional flow-area relationship

KLASS = 2 Conduit with a tabular flow-area relationship

KLASS = 3 Element is not a conduit.

If KLASS = 3, a branch is made to the appropriate routing technique for that particular element type (e.g., manhole, lift station, flow divider). The flow chart of ROUTE is shown in Figure 4-17.

Functional flow-area relationships are those in which the governing equations are actually programmed. This is done only for conduits with simplified geometries, specifically rectangular, modified basket handle, rectangular (triangular bottom), and rectangular (round bottom). All other conduits use tabular data to describe the flow-area curve (discussed later).

Different element types supplied with the Storm Water Management Model are described in Table 4-3.

Conduit Routing (NTYPES 1 to 15 Inclusive). When an element is a conduit, the first step is to determine the slope of the energy grade line (unless the conduit is flowing full because of surcharging). In calculating the energy slope, velocities and normalized depths are found from functions VEL and DEPTH, respectively. The value of the energy slope is used in computing the full flow and maximum flow capacity using Manning's equation and constants specified in subroutine FIRST. When more than one iteration is used for conduits, the energy

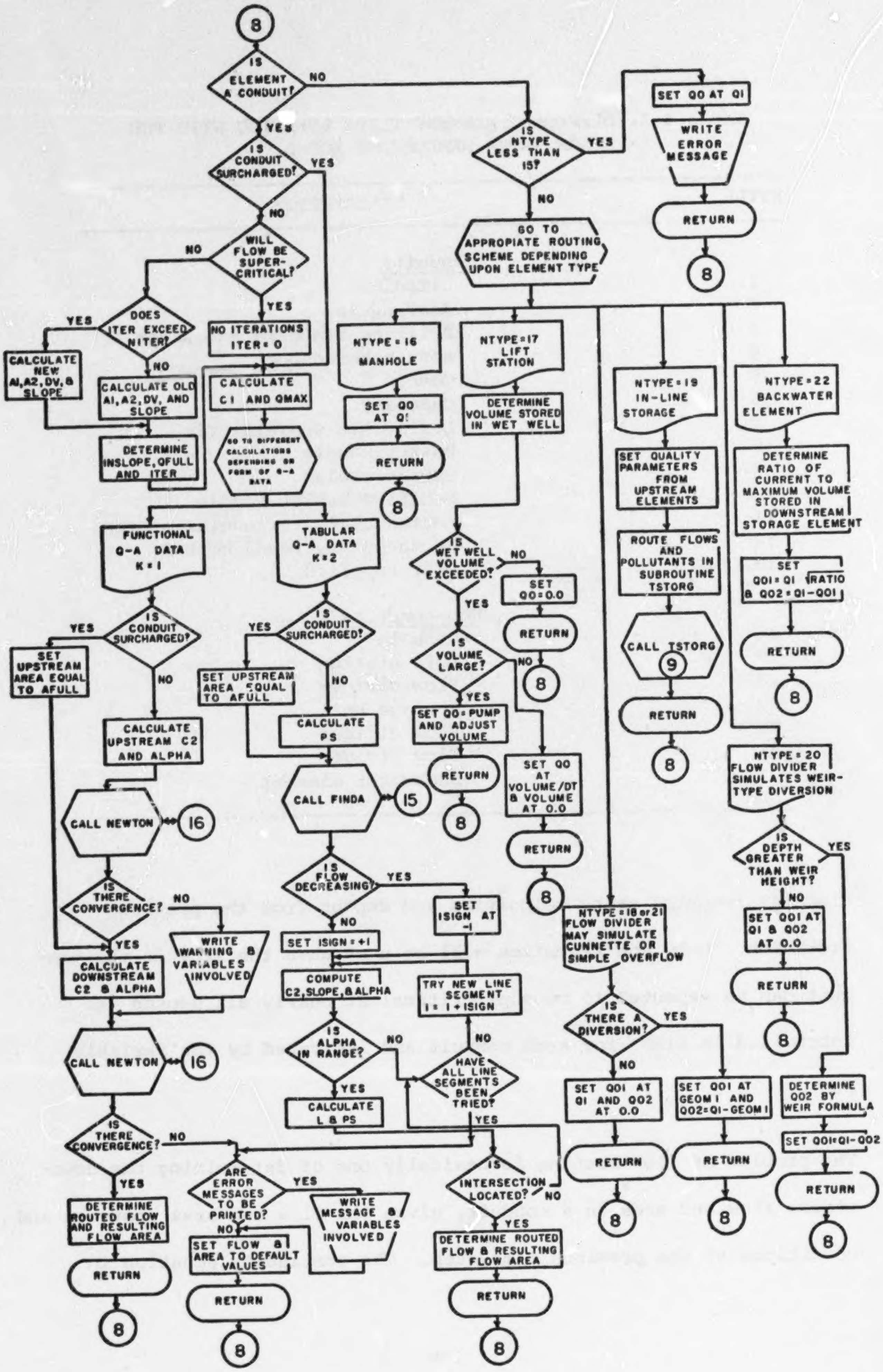

8
IS ELEMENT A CONDUIT?
NO
YES
IS CONDUIT SURCHARGED?
YES
NO
WILL FLOW BE SUPER-CRITICAL?
NO
YES
DOES ITER EXCEED NITER?
YES
NO
CALCULATE NEW A1, A2, DV, & SLOPE
CALCULATE OLD A1, A2, DV, AND SLOPE
DETERMINE INSLOPE, QFULL AND ITER
NO ITERATIONS ITER = 0
CALCULATE C1 AND QMAX
GO TO DIFFERENT CALCULATIONS DEPENDING ON FORM OF Q-A DATA
FUNCTIONAL Q-A DATA K = 1
TABULAR Q-A DATA K = 2
IS CONDUIT SURCHARGED?
YES
NO
SET UPSTREAM AREA EQUAL TO AFULL
CALCULATE UPSTREAM C2 AND ALPHA
CALL NEWTON
16
IS THERE CONVERGENCE?
NO
YES
WRITE WARNING & VARIABLES INVOLVED
CALCULATE DOWNSTREAM C2 & ALPHA
CALL NEWTON
16
IS THERE CONVERGENCE?
NO
YES
DETERMINE ROUTED FLOW AND RESULTING FLOW AREA
RETURN
8
IS CONDUIT SURCHARGED?
YES
NO
SET UPSTREAM AREA EQUAL TO AFULL
CALCULATE PS
CALL FINDA
15
IS FLOW DECREASING?
YES
NO
SET ISIGN AT -1
SET ISIGN = +1
COMPUTE C2, SLOPE, & ALPHA
TRY NEW LINE SEGMENT I = I + ISIGN
IS ALPHA IN RANGE?
NO
YES
HAVE ALL LINE SEGMENTS BEEN TRIED?
NO
YES
CALCULATE L & PS
ARE ERROR MESSAGES TO BE PRINTED?
YES
NO
WRITE MESSAGE & VARIABLES INVOLVED
SET FLOW & AREA TO DEFAULT VALUES
RETURN
8
IS INTERSECTION LOCATED?
NO
YES
DETERMINE ROUTED FLOW & RESULTING FLOW AREA
RETURN
8
IS NTYPE LESS THAN 15?
YES
NO
SET QO AT QI
WRITE ERROR MESSAGE
RETURN
8
GO TO APPROPIATE ROUTING SCHEME DEPENDING UPON ELEMENT TYPE
NTYPE = 16 MANHOLE
SET QO AT QI
RETURN
8
NTYPE = 17 LIFT STATION
DETERMINE VOLUME STORED IN WET WELL
IS WET WELL VOLUME EXCEEDED?
NO
YES
SET QO = 0.0
RETURN
8
IS VOLUME LARGE?
NO
YES
SET QO = PUMP AND ADJUST VOLUME
RETURN
8
SET QO AT VOLUME/DT & VOLUME AT 0.0
RETURN
8
NTYPE = 18 or 21 FLOW DIVIDER MAY SIMULATE CUNNETTE OR SIMPLE OVERFLOW
IS THERE A DIVERSION?
YES
NO
SET QO1 AT QI AND QO2 AT 0.0
SET QO1 AT GEOM1 AND QO2 = QI - GEOM1
RETURN
8
RETURN
8
NTYPE = 19 IN-LINE STORAGE
SET QUALITY PARAMETERS FROM UPSTREAM ELEMENTS
ROUTE FLOWS AND POLLUTANTS IN SUBROUTINE TSTORG
CALL TSTORG
9
RETURN
8
NTYPE = 22 BACKWATER ELEMENT
DETERMINE RATIO OF CURRENT TO MAXIMUM VOLUME STORED IN DOWNSTREAM STORAGE ELEMENT
SET QO1 = QI * RATIO & QO2 = QI - QO1
RETURN
8
NTYPE = 20 FLOW DIVIDER SIMULATES WEIR-TYPE DIVERSION
IS DEPTH GREATER THAN WEIR HEIGHT?
YES
NO
SET QO1 AT QI & QO2 AT 0.0
RETURN
8
DETERMINE QO2 BY WEIR FORMULA
SET QO1 = QI - QO2
RETURN
8

Figure 4-17. SUBROUTINE ROUTE

Table 4-3. DIFFERENT ELEMENT TYPES SUPPLIED WITH THE STORM WATER MANAGEMENT MODEL

NTYPE	DESCRIPTION
	Conduits
1	Circular
2	Rectangular
3	Phillips standard egg shape
4	Boston horseshoe
5	Gothic
6	Catenary
7	Louisville semielliptic
8	Basket-handle
9	Semi-circular
10	Modified basket-handle
11	Rectangular, triangular bottom
12	Rectangular, round bottom
13, 14, 15	User supplied
	Non-conduits
16	Manhole
17	Lift station
18	Flow divider
19	Storage Unit
20	Flow divider
21	Flow divider
22	Backwater element

slope is computed using velocities and depths from the previous iteration. Only one iteration will be used when the flow in the conduit can be expected to be supercritical at nearly all depths (as determined in FIRST for each conduit and indicated by the variable SCF).

The problem of flow routing is basically one of determining the downstream flow and area in a conduit, given the flow and area upstream and conditions at the previous time-step. The continuity equation in finite difference form and Manning's equation based upon the energy slope are used for this purpose. The mathematical problem then becomes one of determining the intersection of the straight line $-C_1\alpha - C_2$ with a normalized flow-area relationship determined from Manning's equation for a particular conduit geometry, as shown in Figure 4-18. In general, the variable α, (ALPHA), represents A/AFULL where A is the cross-sectional area of flow at the upstream or downstream end of the conduit and AFULL is the full-flow area. The variable ψ, (PSI or PS), represents Q/QFULL where Q is the flow at the upstream or downstream end of the conduit and QFULL is the full-flow value.

For a particular element type, the flow-area curve may be given in a functional form, i.e., in its exact mathematical form. In this event (KLASS = 1), the intersection of the straight line and the curve is found using a Newton-Raphson iteration performed in subroutine NEWTON.

The flow-area curve for a particular element type may also be represented in a piecewise-linear or "tabular" form (KLASS = 2). The different line segments describing the curve are then tried until the one is found that intersects the straight line $-C_1\alpha - C_2$ on the curve itself. The value of ALPHA (A/AFULL) at this location is determined and the value of PSI (Q/QFULL) corresponding to ALPHA is also determined.

In the event that no intersection of the curve and the straight line is found (i.e., non-convergence), default values are assigned to the down-

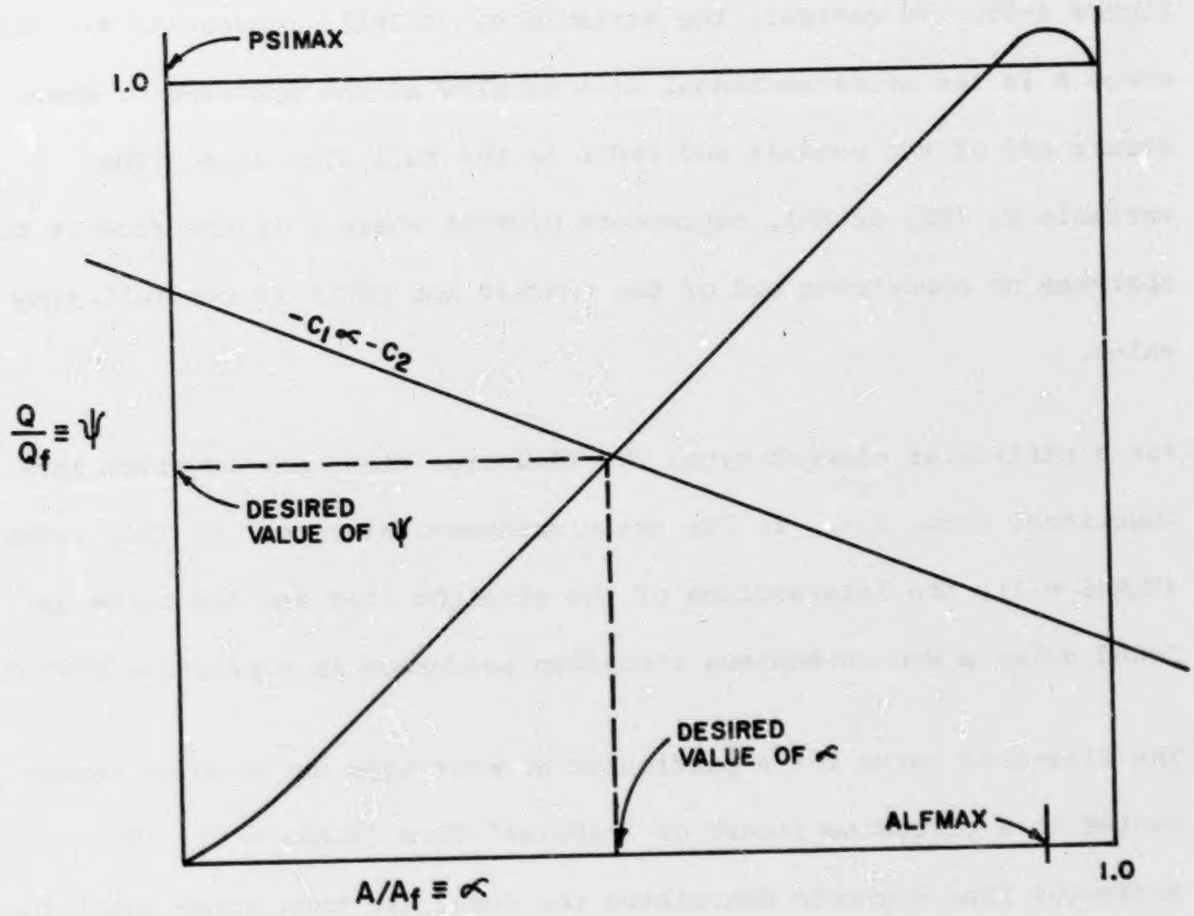


Figure 4-18. THE INTERSECTION OF THE STRAIGHT LINE AND THE NORMALIZED FLOW-AREA CURVE AS DETERMINED IN ROUTE

stream flow and area of the conduit. This occasionally occurs when the conduit is initially dry. (The downstream flow and area will be assigned zero values in this instance.) In the event of non-convergence, a message to that effect will be printed if the variable NPRINT was specified greater than 0.

Routing in Manholes (NTYPE = 16). Flow routing is accomplished in manholes by specifying that the outflow equals the sum of the inflows.

Routing at Lift Stations (NTYPE = 17). When the volume of sewage in the wet well reaches capacity, the pumps begin to operate at a constant rate. This continues until the wet well volume equals zero.

Routing at Flow Dividers(NTYPE = 18 and 21). Both types will divide the inflow, QI, into two outflows, Q01 and Q02. The divider then acts as follows:

$$\begin{array}{lll} \text{For } 0 \leq QI \leq GEOM1 \quad , & Q01 = QI \\ & Q02 = 0.0 \\ \text{For } GEOM1 < QI \quad , & Q01 = GEOM1 \\ & Q02 = QI-GEOM1 \end{array}$$

The undiverted outflow, Q01, will flow into the downstream element denoted by GEOM3. (The element into which flows Q02 does not need to be specified).

Routing at a Flow Divider (NTYPE = 20). This element is used to model a weir-type diversion structure, in which a linear relationship between flow rate and flow depth is assumed to exist. The parameters of the element are defined in Table 4-4.

Table 4-4. PARAMETERS REQUIRED FOR NON-CONDUITS

NTYPE	DESCRIPTION	DIST	GEOM1	SLOPE	ROUGH	GEOM2	BARREL	GEOM3
16	Manhole	N.R.*	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
17	Lift station	Pumping rate, assumed constant (cfs).	Volume in wet well at which pumps will start (cf).	N.R.	N.R.	N.R.	N.R.	N.R.
18	Flow divider	N.R.	Maximum undiverted flow. Inflow in excess of this value is diverted (cfs).	N.R.	N.R.	N.R.	N.R.	Number of element into which flows the undiverted flow (include decimal point).
19	Storage unit**	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	If parameter ISTOUT = 9 for storage unit, GEOM3 = number of element into which flows the outflow from the orifice outlet. Otherwise, N.R.
20	Flow divider	Maximum inflow without flow over the weir (cfs).	Weir height, above zero flow depth (ft).	Maximum inflow through whole structure (cfs).	Weir constant times weir length (ft).	Depth in structure at time of maximum inflow (ft).	N.R.	Number of element into which flows the undiverted flow (weir flow is the diverted flow).
21	Flow divider	N.R.	N.R. (assigned in program)	N.R.	N.R.	N.R.	N.R.	Number of element into which flows the undiverted flow.
22	Backwater element	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	Element number of downstream storage unit.

NOTE: All elements require an element number (NOE), three upstream element numbers (NUE), and type (NTYPE). Parameters for conduits are defined in Table 4-5.

* N.R. = Not required.

** Additional parameters are read in subsequently.

The flow divider behaves as a function of the inflow, QI; as follows:

For Q≤QI≤DIST , Q01 = QI

Q02 = 0.0

For DIST<QI , Q01 and Q02 are computed as follows:

1. Compute depth of flow above the weir, assuming a linear flow-depth relationship:

   DH = (QI-DIST)*(GEOM2-GEOM1)/(SLOPE-DIST)

2. Compute the diverted flow from the weir formula:

   Q02 = ROUGH*DH**1.5

3. Compute the undiverted flow:

   Q01 = QI-Q02.

Routing Through a Storage Element (NTYPE = 19). This element is specified only when internal storage computations are required. The supporting data must have previously been fed into the program in subroutine TSTRDT. The inflowing pollutant concentrations are determined first. Then quantity and quality routing are accomplished in subroutine TSTORG (Figure 4-19), and its subroutines: TSROUT (Figure 4-20) and TPLUGS (Figure 4-21). Subroutine TSTORG is called from ROUTE each time-step to compute movements within the storage unit. TSROUT provides the hydraulic routing computation and TPLUGS traces and identifies the plug elements when the plug flow-through option is selected. If the alternate option, complete mixing, is selected, necessary computations are completed within TSTORG. A more comprehensive description of the storage routines is presented in Section 5 of this manual.

The flow divider behaves as a function of the inflow, QI; as follows:

For $Q \leq QI \leq DIST$, Q01 = QI

Q02 = 0.0

For $DIST < QI$, Q01 and Q02 are computed as follows:

1. Compute depth of flow above the weir, assuming a linear flow-depth relationship:

   DH = (QI-DIST)*(GEOM2-GEOM1)/(SLOPE-DIST)

2. Compute the diverted flow from the weir formula:

   Q02 = ROUGH*DH**1.5

3. Compute the undiverted flow:

   Q01 = QI-Q02.

Routing Through a Storage Element (NTYPE = 19). This element is specified only when internal storage computations are required. The supporting data must have previously been fed into the program in subroutine TSTRDT. The inflowing pollutant concentrations are determined first. Then quantity and quality routing are accomplished in subroutine TSTORG (Figure 4-19), and its subroutines: TSROUT (Figure 4-20) and TPLUGS (Figure 4-21). Subroutine TSTORG is called from ROUTE each time-step to compute movements within the storage unit. TSROUT provides the hydraulic routing computation and TPLUGS traces and identifies the plug elements when the plug flow-through option is selected. If the alternate option, complete mixing, is selected, necessary computations are completed within TSTORG. A more comprehensive description of the storage routines is presented in Section 5 of this manual.

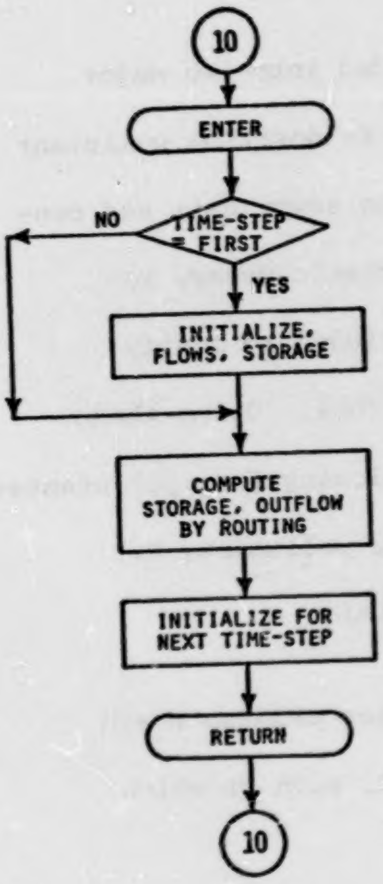

10
ENTER
NO
TIME-STEP = FIRST
YES
INITIALIZE, FLOWS, STORAGE
COMPUTE STORAGE, OUTFLOW BY ROUTING
INITIALIZE FOR NEXT TIME-STEP
RETURN
10

Figure 4-20. SUBROUTINE TSROUT

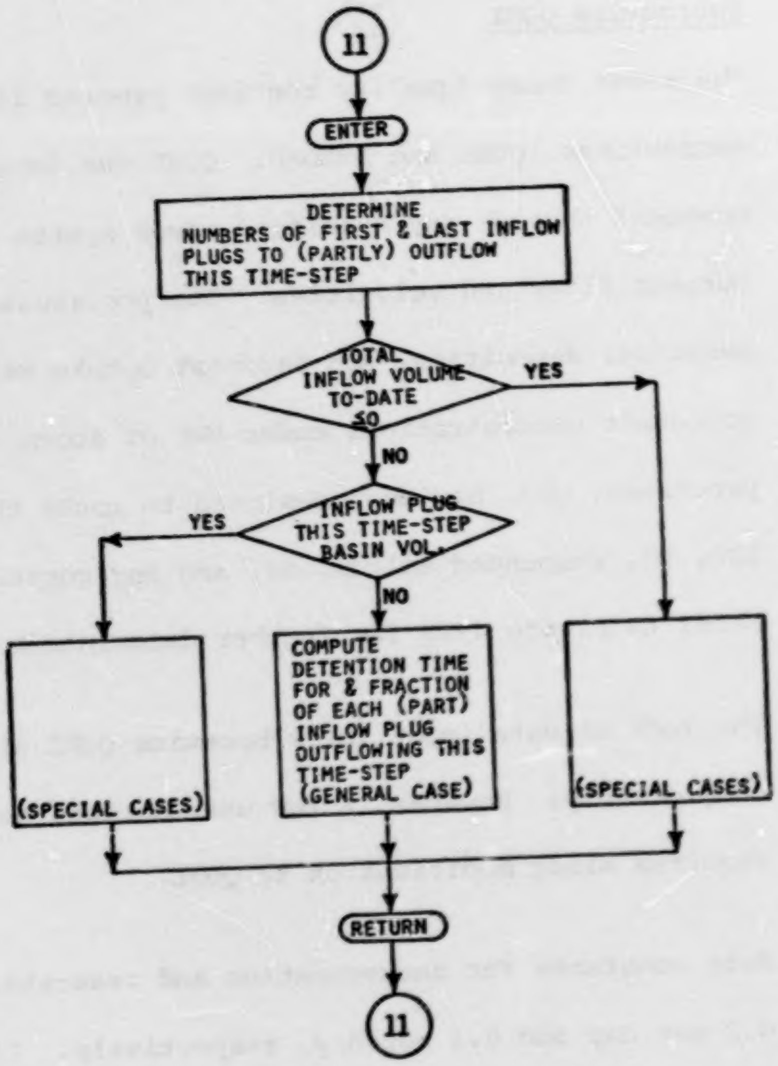

11
ENTER
DETERMINE NUMBERS OF FIRST & LAST INFLOW PLUGS TO (PARTLY) OUTFLOW THIS TIME-STEP
TOTAL INFLOW VOLUME TO-DATE ≤0
YES
NO
INFLOW PLUG THIS TIME-STEP BASIN VOL.
YES
NO
(SPECIAL CASES)
COMPUTE DETENTION TIME FOR & FRACTION OF EACH (PART) INFLOW PLUG OUTFLOWING THIS TIME-STEP (GENERAL CASE)
(SPECIAL CASES)
RETURN
11

Figure 4-21. SUBROUTINE TPLUGS

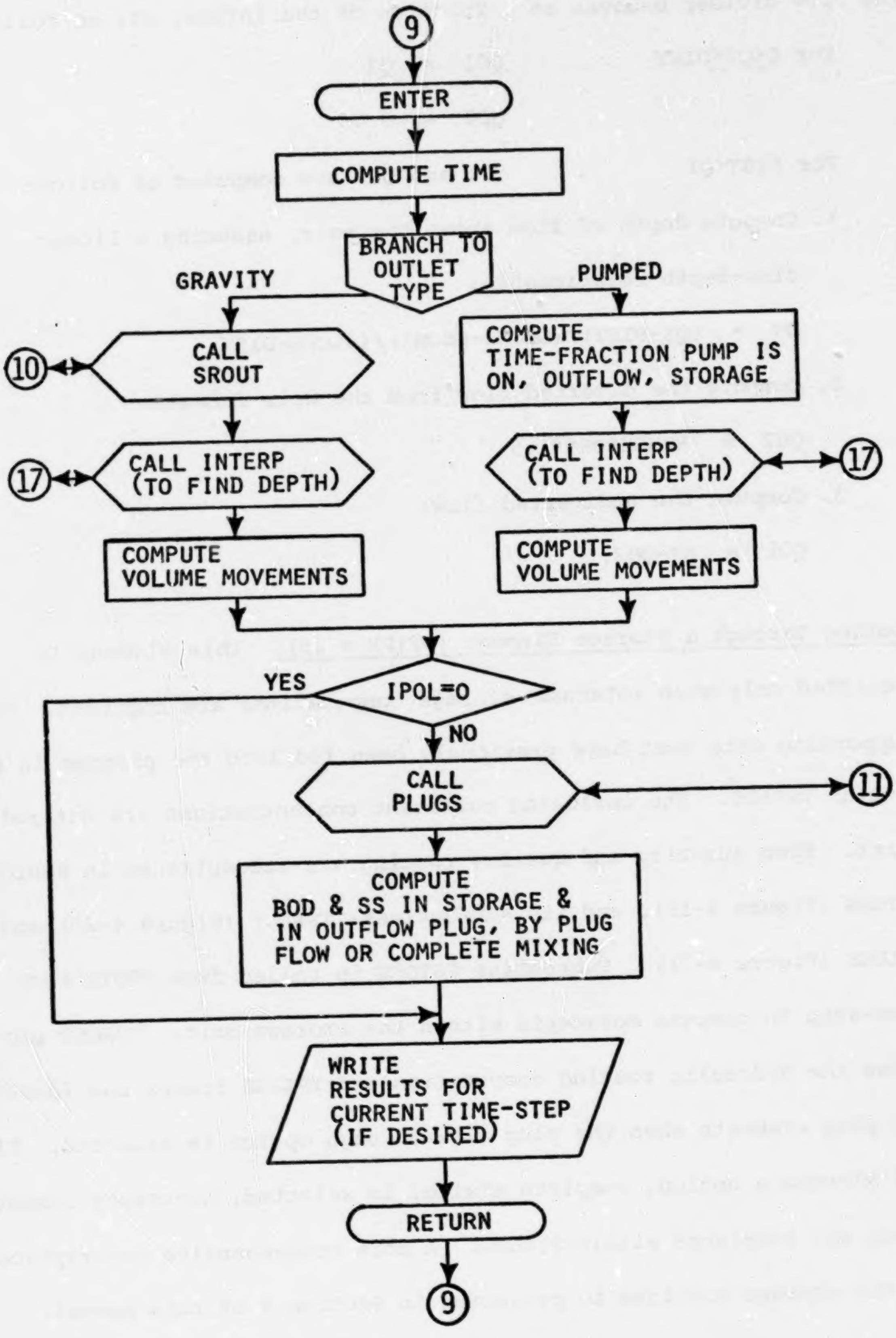

9
ENTER
COMPUTE TIME
BRANCH TO OUTLET TYPE
GRAVITY
PUMPED
CALL SROUT
10
COMPUTE TIME-FRACTION PUMP IS ON, OUTFLOW, STORAGE
CALL INTERP (TO FIND DEPTH)
17
CALL INTERP (TO FIND DEPTH)
17
COMPUTE VOLUME MOVEMENTS
COMPUTE VOLUME MOVEMENTS
YES
IPOL=O
NO
CALL PLUGS
11
COMPUTE BOD & SS IN STORAGE & IN OUTFLOW PLUG, BY PLUG FLOW OR COMPLETE MIXING
WRITE RESULTS FOR CURRENT TIME-STEP (IF DESIRED)
RETURN
9

Figure 4-19. SUBROUTINE TSTORG

Routing at a Backwater Element (NTYPE = 22). The ratio of the volume of flow currently stored in the downstream storage element to the maximum possible storage is determined. The inflow to the storage unit, Q01, is then proportional to the square root of this ratio.

Subroutine QUAL ⑫

The sewer decay (quality routing) program is divided into two major subroutines, QUAL and DWLOAD. QUAL was developed to describe pollutant movement through any specified sewer system , given sewer data and concurrent flows and velocities. The processes of organic decay, reaeration, deposition, and sediment uptake were included to modify pollutant concentrations under DWF or storm conditions. Using these processes, QUAL has been designed to route the following four pollutants: BOD, DO, suspended solids, SS, and any conservative pollutant, P. Refer to Figure 4-22 for further descriptions of QUAL.

The lack of data input for subroutine QUAL simplifies program usage considerably. However, a few user options do exist, each of which requires minor modification to QUAL.

Rate constants for deoxygenation and reaeration have been chosen as 0.2 per day and 0.3 per day, respectively. If locally observed rate constants for flowing sewage have been determined, these should be used to recalculate D1 in the section on BOD and D1 and D2 in the section on DO in QUAL. Likewise, assumed saturation of 7 mg/L should be replaced by inserting a more appropriate value of S under the section on DO in QUAL.

BLANK PAGE

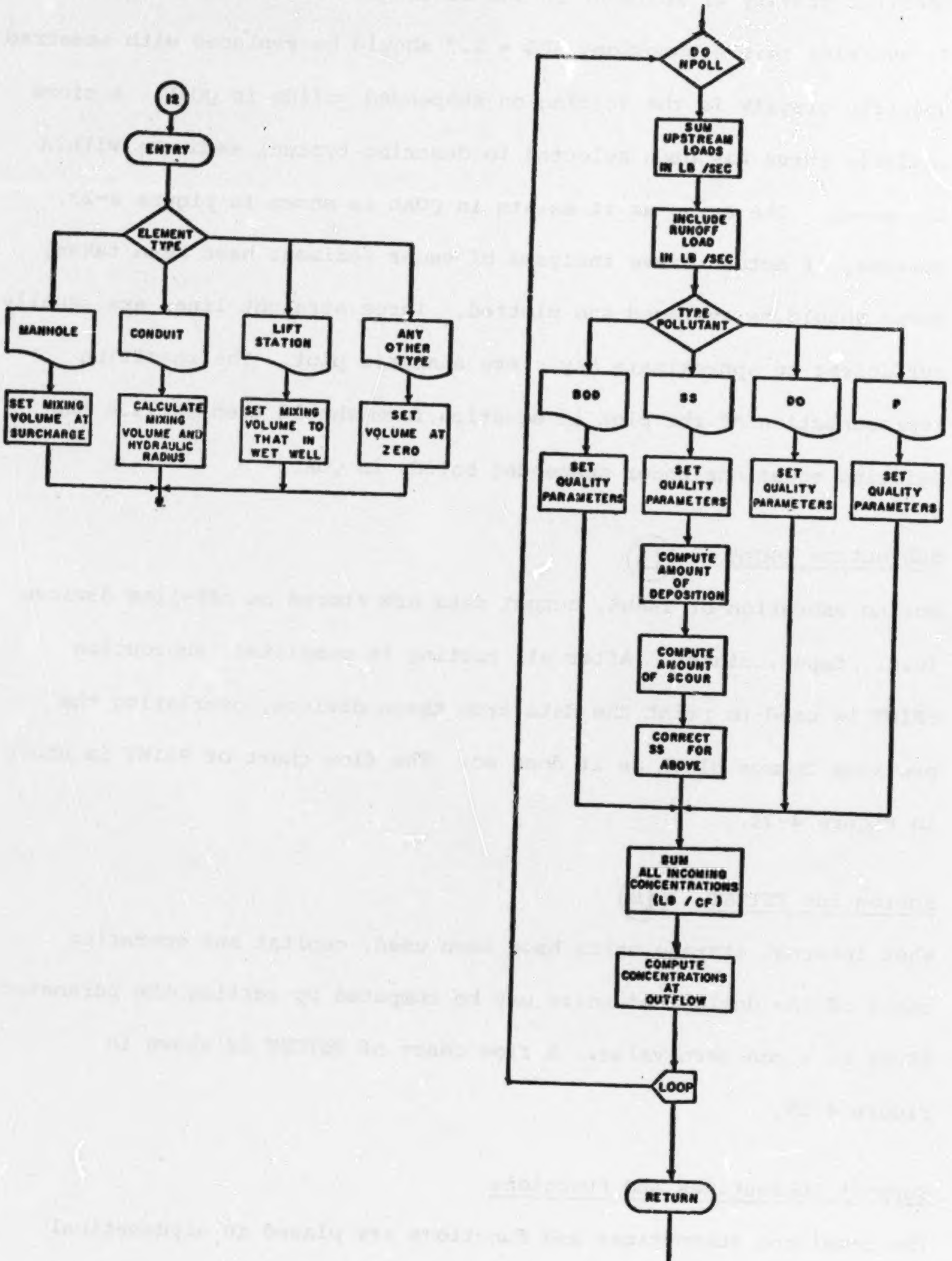

12
ENTRY
ELEMENT TYPE
MANHOLE
CONDUIT
LIFT STATION
ANY OTHER TYPE
SET MIXING VOLUME AT SURCHARGE
CALCULATE MIXING VOLUME AND HYDRAULIC RADIUS
SET MIXING VOLUME TO THAT IN WET WELL
SET VOLUME AT ZERO
DO NPOLL
SUM UPSTREAM LOADS IN LB /SEC
INCLUDE RUNOFF LOAD IN LB /SEC
TYPE POLLUTANT
BOD
SS
DO
P
SET QUALITY PARAMETERS
SET QUALITY PARAMETERS
SET QUALITY PARAMETERS
SET QUALITY PARAMETERS
COMPUTE AMOUNT OF DEPOSITION
COMPUTE AMOUNT OF SCOUR
CORRECT SS FOR ABOVE
SUM ALL INCOMING CONCENTRATIONS (LB / CF)
COMPUTE CONCENTRATIONS AT OUTFLOW
LOOP
RETURN
12

Figure 4-22. SUBROUTINE QUAL

Specific gravity of sediment in the sewer has been assumed as 2.70. To override this assumption, SPG = 2.7 should be replaced with measured specific gravity in the section on suspended solids in QUAL. A sieve analysis curve has been selected to describe typical sediment within the sewer. The curve as it exists in QUAL is shown in Figure 4-23. However, if actual sieve analyses of sewer sediment have been taken, these should be averaged and plotted. Three straight lines are usually sufficient to approximate any sieve analysis plot. The resulting representation of the plot in equation form should then replace the existing equations under suspended solids in QUAL.

Subroutine PRINT ⑬

During execution of TRANS, output data are stored on off-line devices (e.g., tapes, disks). After all routing is completed, subroutine PRINT is used to print the data from these devices, overlaying the previous common block as it does so. The flow chart of PRINT is shown in Figure 4-24.

Subroutine TSTCST ⑭

When internal storage units have been used, capital and operating costs of the designated units may be computed by setting the parameter ICOST to a non-zero value. A flow chart of TSTCST is shown in Figure 4-25.

Support Subroutines and Functions

The remaining subroutines and functions are placed in alphabetical order since they may be called by several different subroutines.

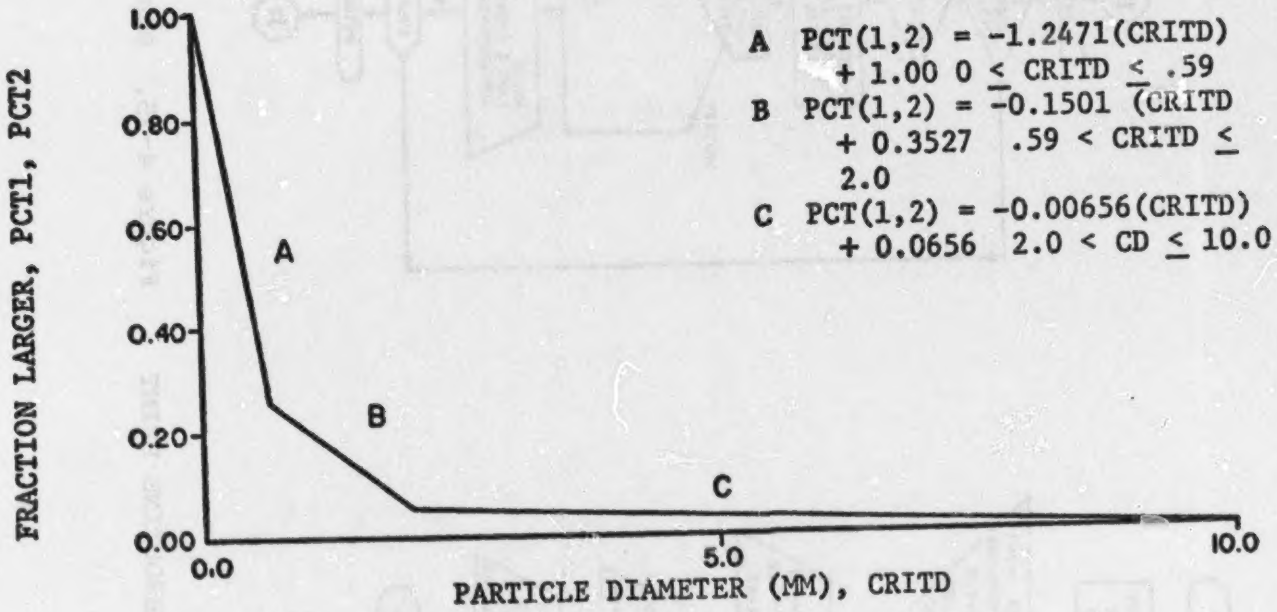


Figure 4-23. SIEVE ANALYSIS PLOT FOR SEWER SEDIMENT

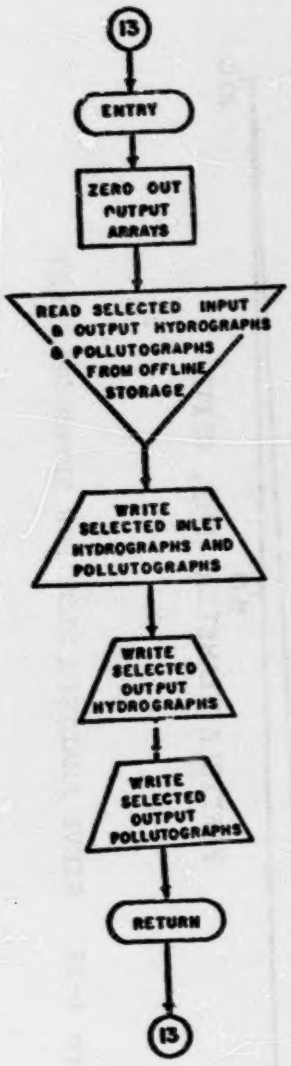

13
ENTRY
ZERO OUT OUTPUT ARRAYS
READ SELECTED INPUT & OUTPUT HYDROGRAPHS & POLLUTOGRAPHS FROM OFFLINE STORAGE
WRITE SELECTED INLET HYDROGRAPHS AND POLLUTOGRAPHS
WRITE SELECTED OUTPUT HYDROGRAPHS
WRITE SELECTED OUTPUT POLLUTOGRAPHS
RETURN
13

Figure 4-24. SUBROUTINE PRINT

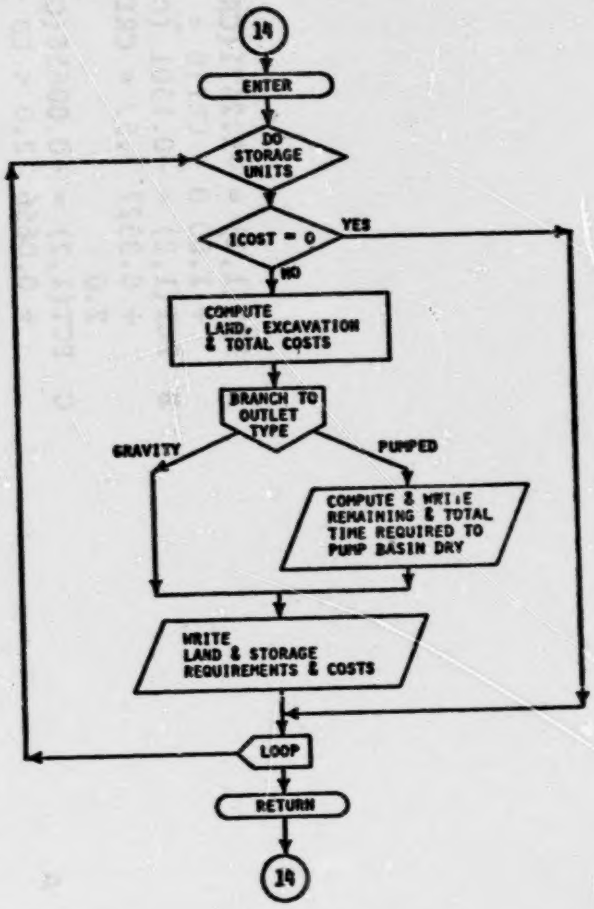

14
ENTER
DO STORAGE UNITS
ICOST = 0
YES
NO
COMPUTE LAND, EXCAVATION & TOTAL COSTS
BRANCH TO OUTLET TYPE
GRAVITY
PUMPED
COMPUTE & WRITE REMAINING & TOTAL TIME REQUIRED TO PUMP BASIN DRY
WRITE LAND & STORAGE REQUIREMENTS & COSTS
LOOP
RETURN
14

Figure 4-25. SUBROUTINE TSTCST

Block Data. This subprogram initializes, through the use of DATA statements, several arrays in the common blocks labeled "NAMES" and "TABLES." Most of these arrays contain data used during the flow routing process, such as the flow-area and depth-area curves. The data for the supplied conduit shapes are stored here.

Function DEPTH. ⑱ This function determines the normalized depth of flow in a conduit, given the normalized area of flow for a conduit with either a functional (KDEPTH = 1) or tabular (KDEPTH = 2) depth-area relationship. A flow chart of DEPTH is shown in Figure 4-26.

Function DPSI. ⑲ This function returns a value of the derivative ($d\psi/d\alpha$) of the normalized flow (ψ)-area(α) curve for a functional relationship. The equations describing the derivative of the flow-area curves for four conduits are programmed. Function PSI must have been called immediately prior to calling DPSI because certain scratch variables must be initialized in PSI. This will always be the case as long as DPSI is called only from NEWTON. A flow chart of DPSI is shown in Figure 4-27.

Subroutine FINDA. ⑮ This subroutine, called from DWLOAD, ROUTE, and INITAL, determines the flow area given the flow rate in conduits with either tabular or functional flow-area curves. In the event of a functional curve, the area is found from a Newton-Raphson iteration in subroutine NEWTON. A flow chart of FINDA is shown in Figure 4-28.

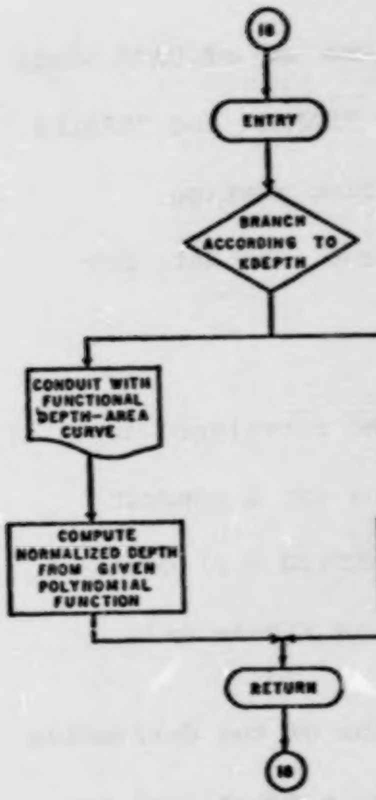

18
ENTRY
BRANCH ACCORDING TO KDEPTH
CONDUIT WITH FUNCTIONAL DEPTH-AREA CURVE
CONDUIT WITH TABULAR DEPTH-AREA CURVE
COMPUTE NORMALIZED DEPTH FROM GIVEN POLYNOMIAL FUNCTION
FIND NORMALIZED DEPTH FROM TABLE BY LINEAR INTERPOLATION
RETURN
18

Figure 4-26. FUNCTION DEPTH

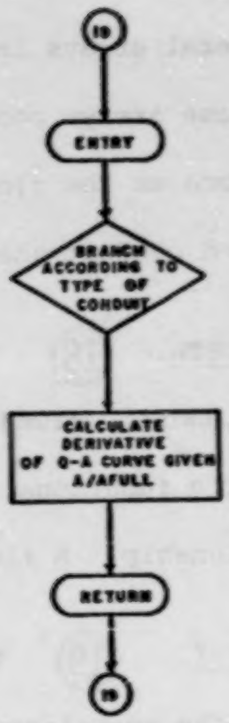

19
ENTRY
BRANCH ACCORDING TO TYPE OF CONDUIT
CALCULATE DERIVATIVE OF Q-A CURVE GIVEN A/AFULL
RETURN
19

Figure 4-27. FUNCTION DPSI

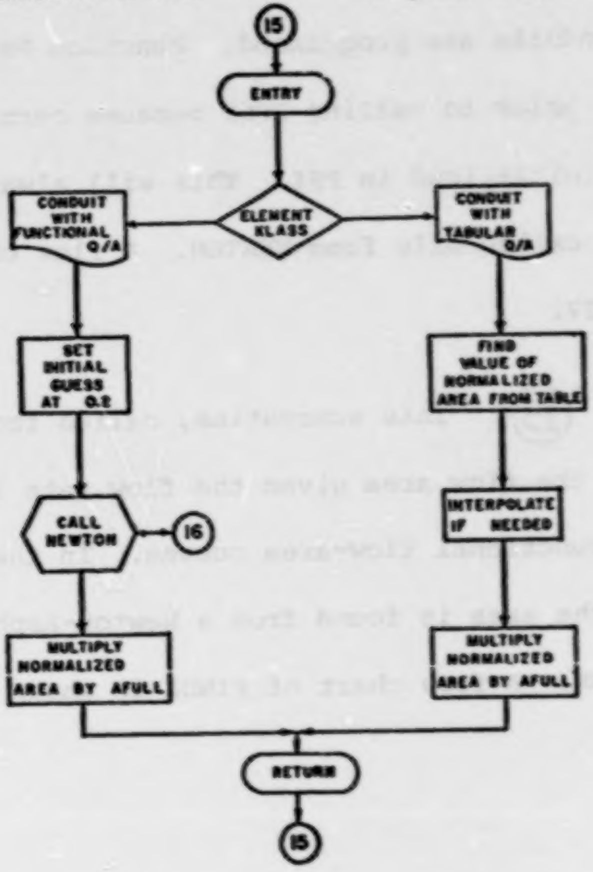

15
ENTRY
ELEMENT KLASS
CONDUIT WITH FUNCTIONAL Q/A
CONDUIT WITH TABULAR Q/A
SET INITIAL GUESS AT 0.2
FIND VALUE OF NORMALIZED AREA FROM TABLE
CALL NEWTON
16
INTERPOLATE IF NEEDED
MULTIPLY NORMALIZED AREA BY AFULL
MULTIPLY NORMALIZED AREA BY AFULL
RETURN
15

Figure 4-28. SUBROUTINE FINDA

Subroutine NEWTON. ⑯ This subroutine performs a Newton-Raphson iteration to determine the intersection of the straight line $-C_1\alpha - C_2$ with the normalized flow-area (ψ-α) curve given in functional form. Functions PSI and DPSI return values of $\psi(\alpha)$ and $d\psi(\alpha)/d\alpha$, respectively. The value of KFLAG is set to one if there is convergence and to two if there is not. The flow chart of NEWTON is shown in Figure 4-29.

Function PSI. ⑳ This function returns a value of normalized flow (ψ), given a value of normalized area (α) for conduits with a functional flow-area curve. The equations describing the flow-area curves for four conduits are programmed. A flow chart of PSI is shown in Figure 4-30.

Function RADH. ㉑ This function determines the hydraulic radius, given the area of flow in a conduit. It is found exactly for circular, rectangular (including triangular and round bottoms), and modified basket-handle conduits. For other types, the diameter of an equivalent circular conduit is found, (i.e., one with an equal full-flow area). The hydraulic radius is then found using the given flow area and the equivalent circular section. The flow chart of RADH is shown in Figure 4-31.

Subroutine TINTRP. ⑰ This subroutine performs simple linear interpolation between points identified by coordinate values. The flow chart for TINTRP is shown in Figure 4-32.

Function VEL. ㉒ This function calculates a velocity by dividing the flow by the area. The reason for having a separate function for this purpose is that it also checks for zero flow and area to avoid a divide

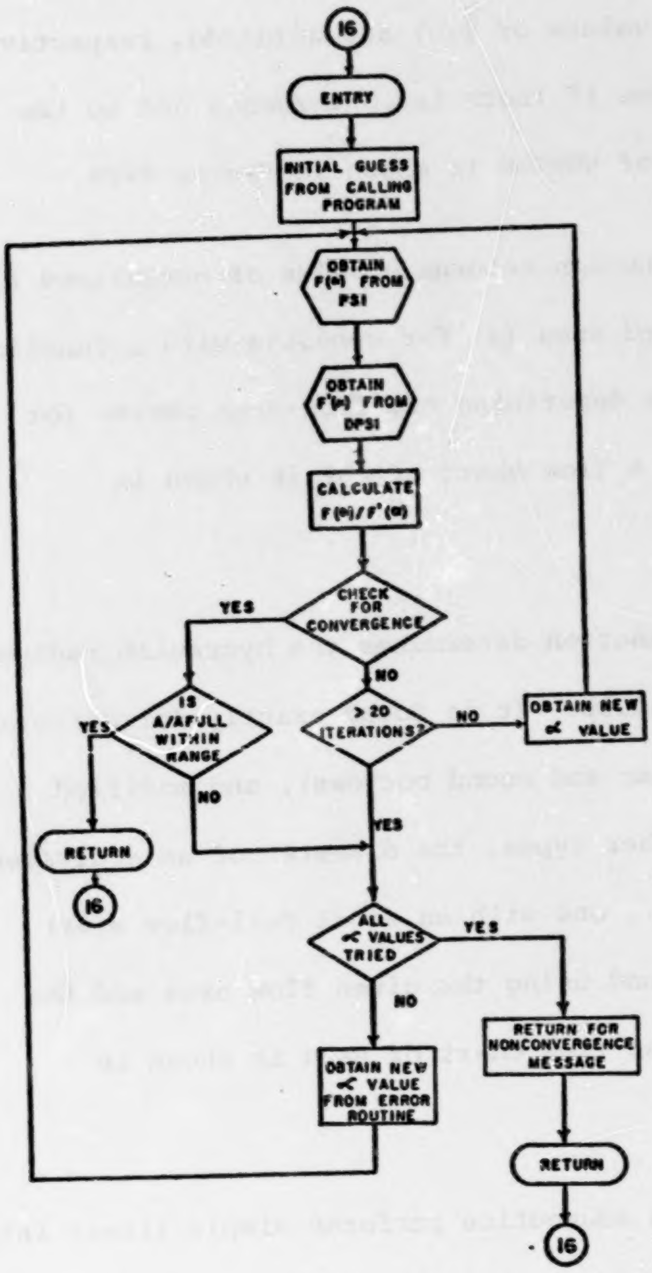

16
ENTRY
INITIAL GUESS FROM CALLING PROGRAM
OBTAIN F(α) FROM PSI
OBTAIN F'(α) FROM DPSI
CALCULATE F(α)/F'(α)
CHECK FOR CONVERGENCE
YES
NO
IS A/AFULL WITHIN RANGE
YES
NO
RETURN
16
> 20 ITERATIONS?
NO
YES
OBTAIN NEW α VALUE
ALL α VALUES TRIED
YES
NO
OBTAIN NEW α VALUE FROM ERROR ROUTINE
RETURN FOR NONCONVERGENCE MESSAGE
RETURN
16

Figure 4-29. SUBROUTINE NEWTON

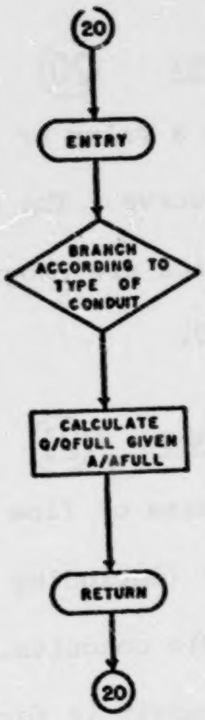

20
ENTRY
BRANCH ACCORDING TO TYPE OF CONDUIT
CALCULATE Q/QFULL GIVEN A/AFULL
RETURN
20

Figure 4-30. FUNCTION PSI

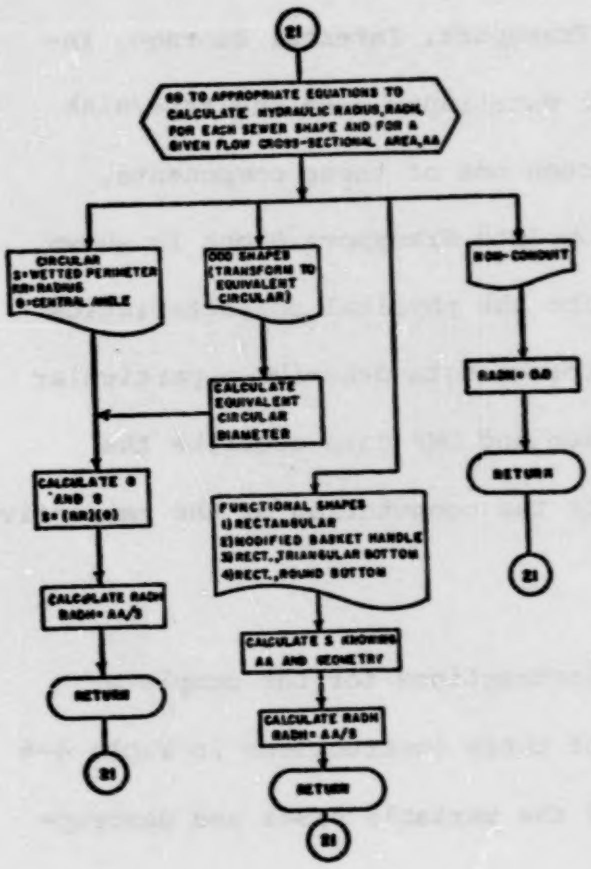

21
GO TO APPROPRIATE EQUATIONS TO CALCULATE HYDRAULIC RADIUS, RADH, FOR EACH SEWER SHAPE AND FOR A GIVEN FLOW CROSS-SECTIONAL AREA, AA
CIRCULAR S=WETTED PERIMETER RR=RADIUS θ=CENTRAL ANGLE
ODD SHAPES (TRANSFORM TO EQUIVALENT CIRCULAR)
NON-CONDUIT
CALCULATE EQUIVALENT CIRCULAR DIAMETER
RADH= 0.0
RETURN
21
CALCULATE θ AND S S=(RR)(θ)
FUNCTIONAL SHAPES 1) RECTANGULAR 2) MODIFIED BASKET HANDLE 3) RECT., TRIANGULAR BOTTOM 4) RECT., ROUND BOTTOM
CALCULATE RADH RADH= AA/S
CALCULATE S KNOWING AA AND GEOMETRY
RETURN
21
CALCULATE RADH RADH= AA/S
RETURN
21

Figure 4-31. FUNCTION RADH

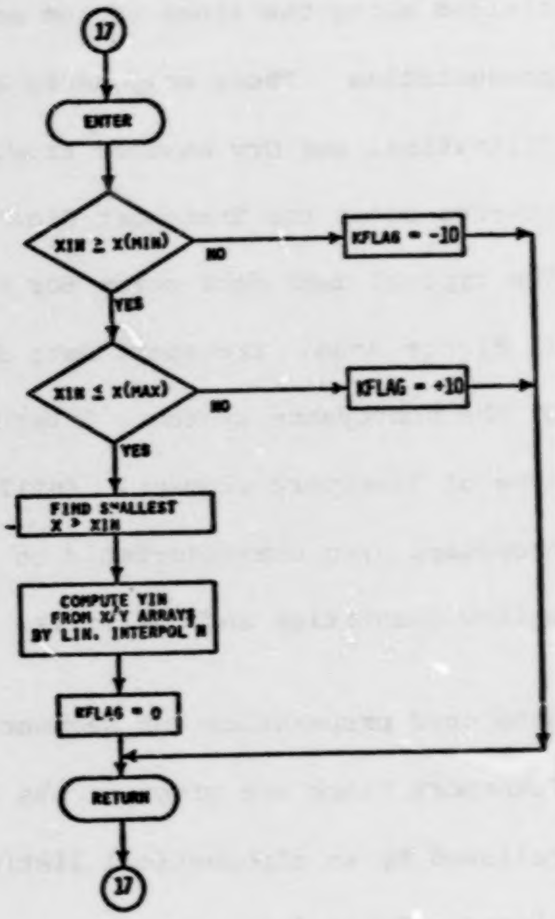

17
ENTER
XIN ≥ X(MIN)
NO
YES
KFLAG = -10
XIN ≤ X(MAX)
NO
YES
KFLAG = +10
FIND SMALLEST X > XIN
COMPUTE YIN FROM X/Y ARRAYS BY LIN. INTERPOL'N
KFLAG = 0
RETURN
17

Figure 4-32. SUBROUTINE TINTRP

check error during program execution. Flow chart for VEL is given in Figure 4-33.

INSTRUCTIONS FOR DATA PREPARATION

Instructions for data preparation for the Transport Block have been divided along the lines of the major components for clarity of the presentation. These components are: Transport, Internal Storage, Infiltration, and Dry Weather Flow. All data input card and tape/disk sources enter the Transport Block through one of these components. The typical data deck setup for the complete Transport Block is shown in Figure 4-34. Transport data describe the physical characteristics of the conveyance system. Internal Storage data describe a particular type of Transport element. Infiltration and DWF data describe the necessary area characteristic to permit the computation of the respective inflow quantities and qualities.

Data card preparation and sequencing instructions for the complete Transport Block are given at the end of these instructions in Table 4-6 followed by an alphabetical listing of the variable names and descriptions in Table 4-7.

Transport Model

Use of the Transport program involves three primary steps:

- Step 1 - Preparation of theoretical data for use by subroutines engaged in hydraulic calculations in the program.
- Step 2 - Preparation of physical data describing the combined sewer system.

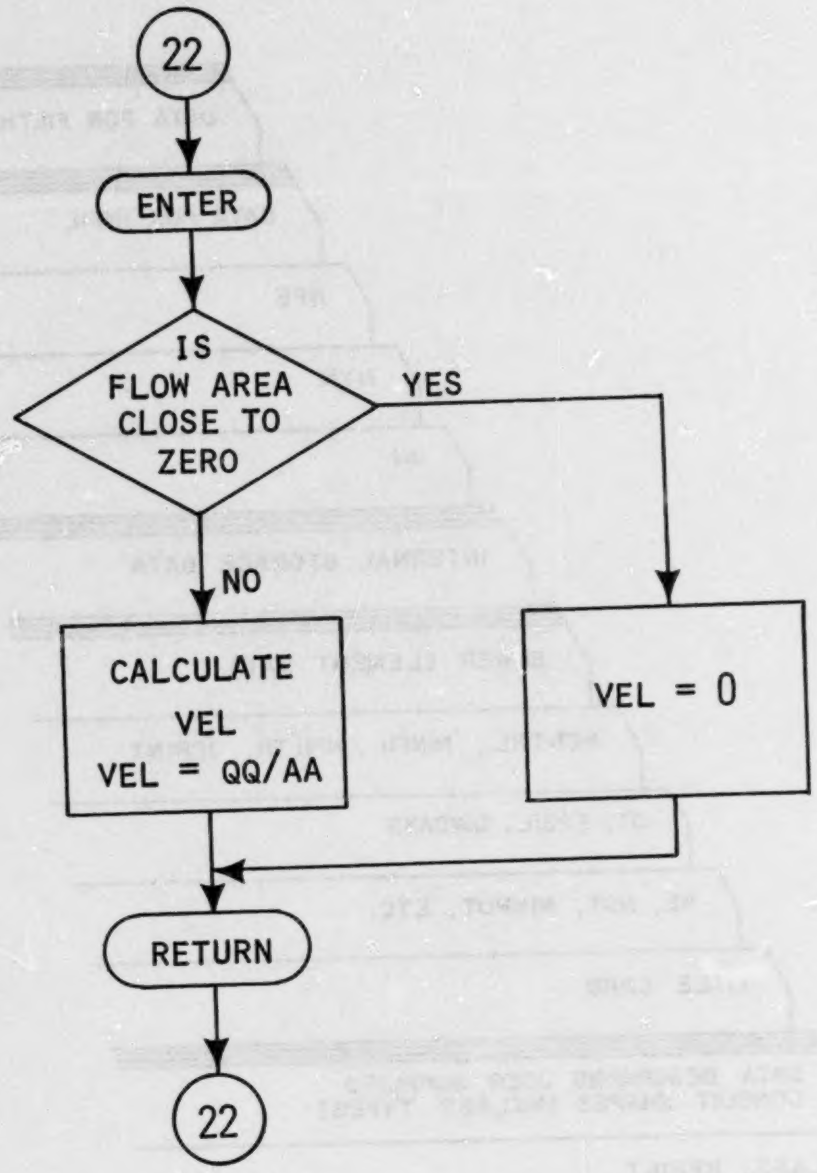

22
ENTER
IS FLOW AREA CLOSE TO ZERO
YES
NO
CALCULATE VEL
VEL = QQ/AA
VEL = 0
RETURN
22

Figure 4-33. FUNCTION VEL

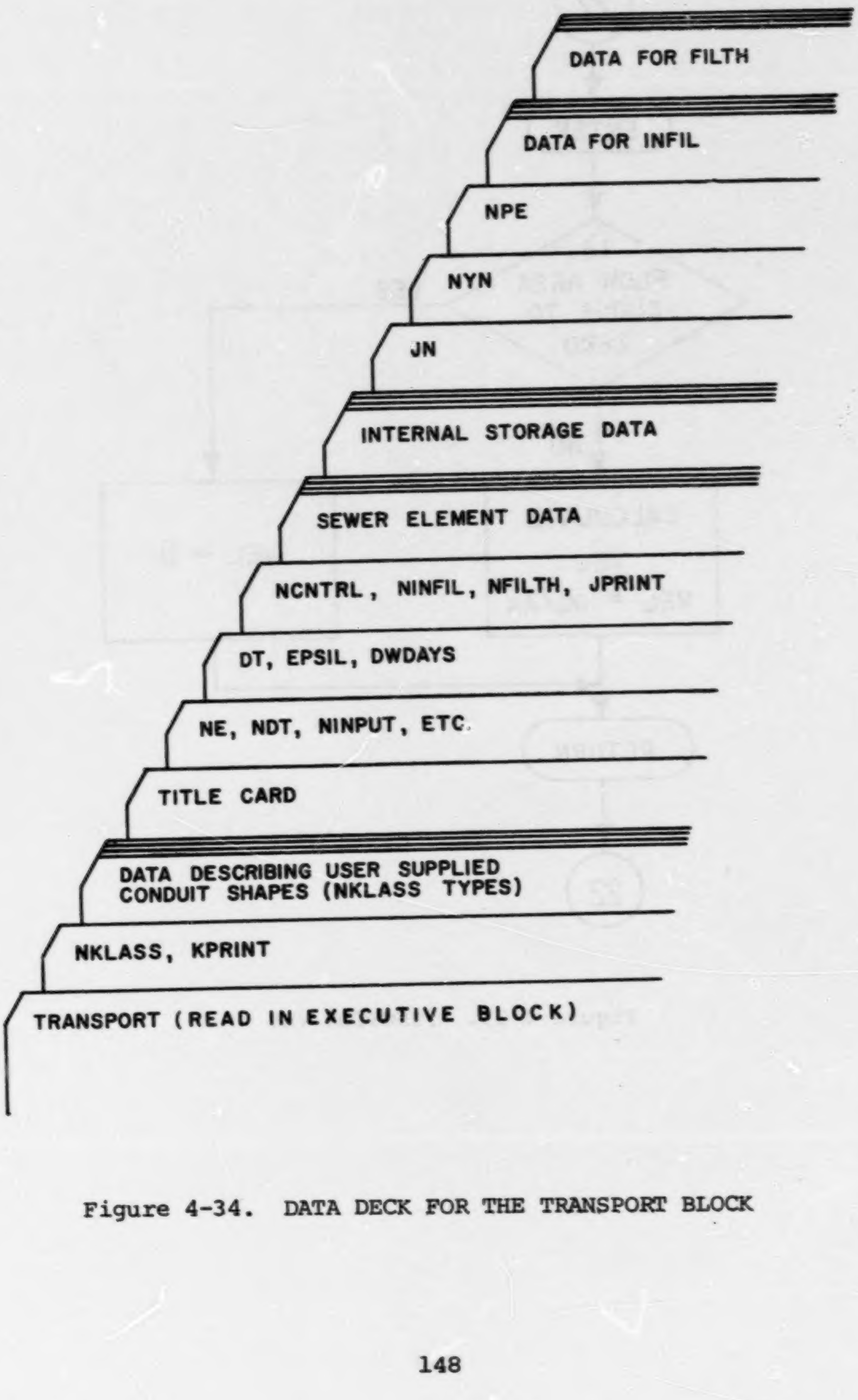

DATA FOR FILTH
DATA FOR INFIL
NPE
NYN
JN
INTERNAL STORAGE DATA
SEWER ELEMENT DATA
NCNTRL, NINFIL, NFILTH, JPRINT
DT, EPSIL, DWDAYS
NE, NDT, NINPUT, ETC.
TITLE CARD
DATA DESCRIBING USER SUPPLIED CONDUIT SHAPES (NKLASS TYPES)
NKLASS, KPRINT
TRANSPORT (READ IN EXECUTIVE BLOCK)

Figure 4-34. DATA DECK FOR THE TRANSPORT BLOCK

Step 3 - Generation of inlet hydrographs and pollutographs required as input to the Transport Model and computational controls.

Data for Step 1 are supplied with the Storm Water Management program for 12 different conduit shapes, and it will only be necessary for the user to generate supplemental data in special instances. These instances will occur only when conduit sections of very unusual geometry are incorporated into the sewer system. Generation of such data will be discussed below.

The primary data requirements for the user are for Step 2, the physical description of the combined sewer system. This means, essentially, the tabulation of sewer shapes, dimensions, slopes, roughness, etc., which will be discussed in detail below.

The data for Step 3 will be generated by the Runoff Block, described in Section 3 of this manual, and by subroutine INFIL and FILTH.

Step 1 - Theoretical Data. The first data read by TRANS describe the number and types of different conduit shapes found in the system. Only in the case of a very unusual shape should it become necessary to generate theoretical data to supplement the data supplied by the program. The required data describe flow-area relationships of conduits, as shown in Figure 4-18, through the parameters ANORM and QNORM. A similar depth-area relationship is also required, using the parameter DNORM.

The flow-area data are generated from Manning's equation, normalized by dividing by the corresponding equation for the conduit flowing full, denoted by the subscript f. Thus,

$$Q/Q_f = A*R**0.667/(A_f*R_f**0.667) = f(A/A_f) \tag{7}$$

where Q = Flow

A = Flow area

R = Hydraulic radius.

For a given conduit shape (e.g., circular, rectangular, horseshoe), the hydraulic radius is a unique function of the area of flow; hence, Q/Q_f is a function only of A/A_f. This function is tabulated for circular conduits in Appendix I of Ref. 9, for example, and on page 443 of Ref.10 for a Boston horseshoe section. It is shown in graphical form for several conduit shapes in Chapter XI, Ref. 11,from which some data supplied with this program have been generated. A list of the conduit shapes supplied with the Storm Water Management program as well as all other element types was given in Table 4-3. The conduits are illustrated in Figure 4-35.

It will often be satisfactory to represent a shape not included in Table 4-3 by one in the list of similar geometry, to be discussed later. This use of "equivalent" sewer sections will avoid the problem of generating flow-area and depth-area data. An equivalent section is defined as a conduit shape from Table 4-3 whose dimensions are such that its cross-sectional area and the area of the actual conduit are equal. Only very small errors should result from the flow routing when this is done.

If it is desired to have the exact flow-area and depth-area relationships, then the product $AR^{2/3}$ must be found as a function of area. In general, the mathematical description of the shape will be complex and the task is most easily carried out graphically. Areas may be planimetered, and the wetted perimeter measured to determine R. In addition, the depth may be measured with a scale. The required flow-area relationship of Eq. (7) may then be tabulated as can the depth-area relationship. The number of points on the flow-area and depth-area curves required to describe the curves is an input variable (MM and NN, respectively). Note that the normalized flows (QNORM) and depths (DNORM) must be tabulated at points corresponding to MM-1 and NN-1, respectively, equal divisions of the normalized area axis (ANORM).

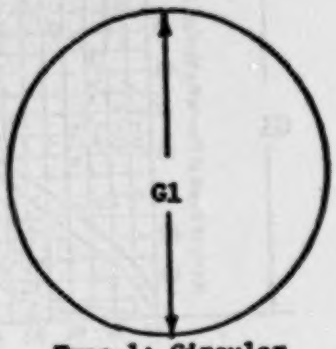
Step 2 - The Physical Representation of the Sewer System. These data are the different element types of the sewer system and their physical descriptions. The system must first be identified as a system of conduit lengths, joined at manholes (or other non-conduits). In addition, either real or hypothetical manholes should delineate significant changes in conduit geometry, dimensions, slope, or roughness. Finally, inflows to the system (i.e., storm water, wastewater, and infiltration) are allowed to enter only at manholes (or other non-conduits). Thus manholes must be located at points corresponding to inlet points for hydrographs generated by the Runoff Block and input points specified in subroutines FILTH and INFIL. In general, the task of identifying elements of the sewer system will be done most conveniently in conjunction with the preparation of data for these other subroutines.

Description of Conduits

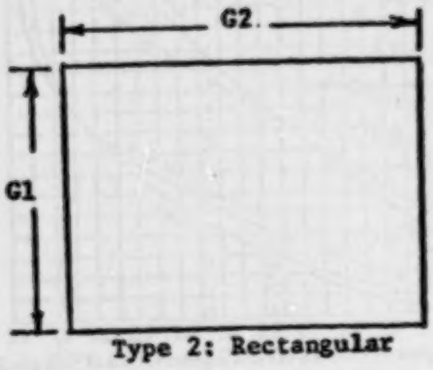
The 12 conduit shapes supplied with the Storm Water Management program are shown in Figure 4-35. For each shape, the required dimensions are illustrated in the figure and specified in Table 4-5. In addition, Table 4-5 gives the formula for calculating the total cross-sectional area of the conduit.

Usually, the shape and dimensions of the conduit will be indicated on plans. It is then a simple matter to refer to Figure 4-35 for the proper conduit type and dimensions. If the shape does not correspond to any supplied by the program, it will ordinarily suffice to choose a shape corresponding most nearly to the one in question. For example, an inverted egg can be reasonably approximated by a catenary section. The dimensions of the substitute shape should be chosen so that the area of the substitute conduit and that of the actual conduit are the same. This is facilitated by Table 4-5, in which the area is given as a function of the conduit dimensions. If desired, the flow-depth-area parameters for up to three additional conduit shapes may be read in at the beginning of the program. (See Card Groups 2-10, Table 4-6.)

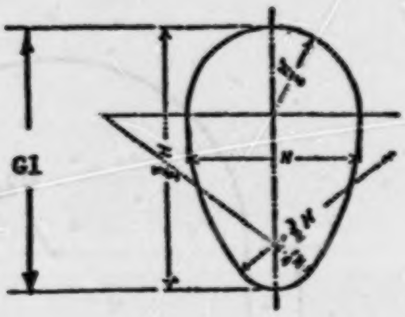
Occasionally, the conduit dimensions and area may be given, but the shape not specified. It will sometimes be possible to deduce the shape from the given information. For example, a conduit may have an area of 4.58 square feet and dimensions of 2 feet by 3 feet. First, assume that the 2-foot dimension is the width, and the 3-foot dimension is the depth of the conduit. Second, note from Figure 4-35 that the ratio of depth to width for an egg-shaped conduit is 1.5:1. Finally, the area



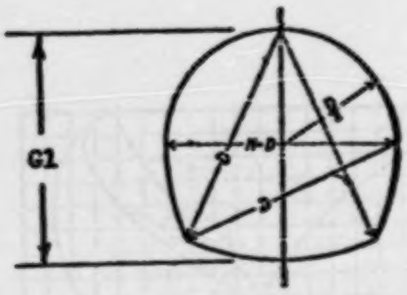
Type 1: Circular



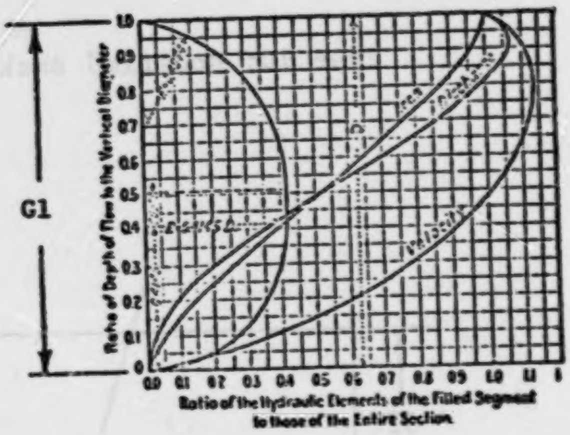
Type 2: Rectangular



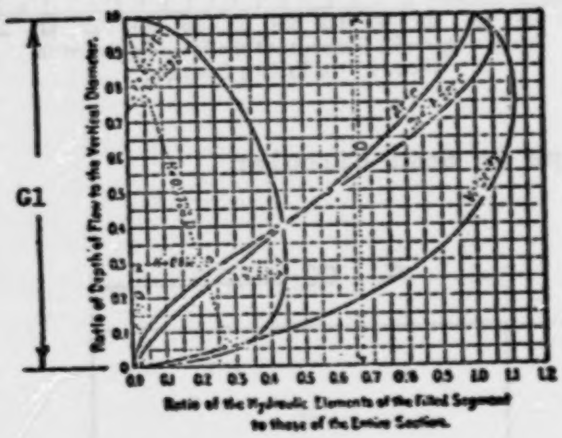
Type 3: Phillips Standard Egg Shape



Type 4: Boston Horseshoe

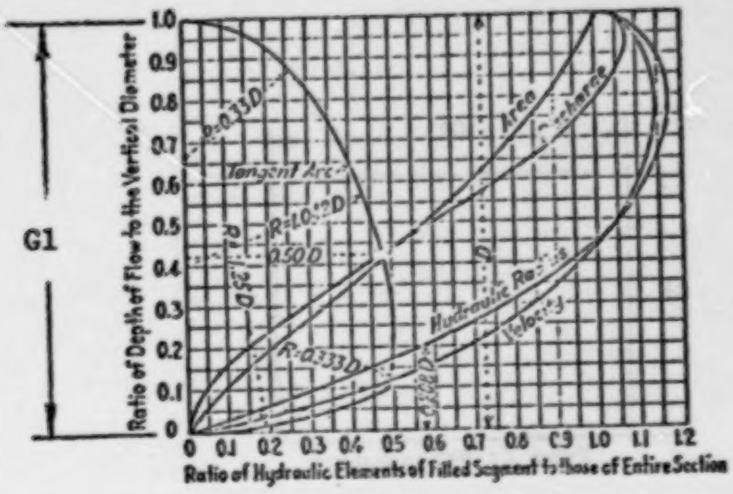


Type 5: Gothic

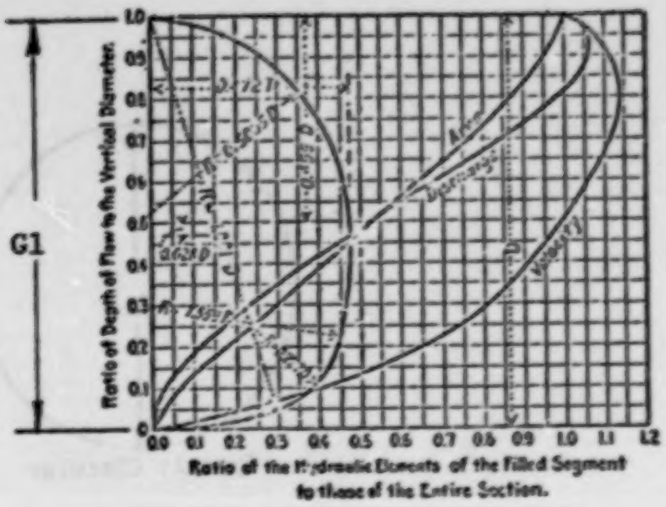


Type 6: Catenary

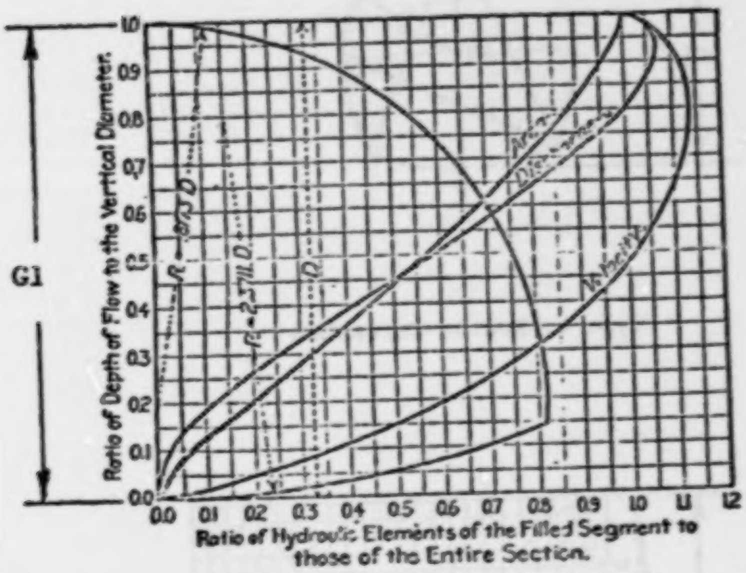
Figure 4-35. SEWER CROSS-SECTIONS

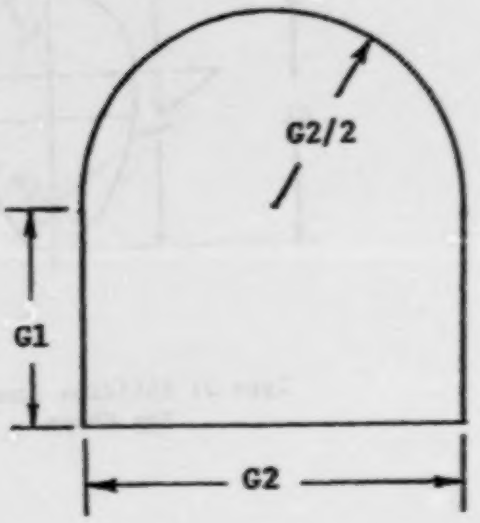


Type 7: Louisville Semielliptic



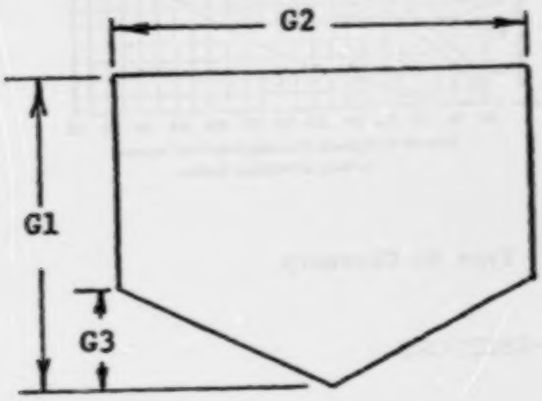
Type 8: Basket-handle

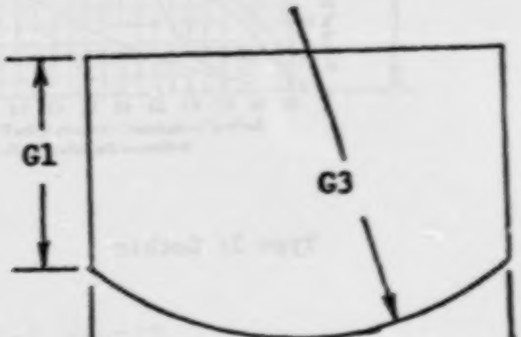




Type 10: Modified Basket-handle

Type 9: Semi-circular





Type 11: Rectangular, Triangular Bottom

Type 12: Rectangular, Round Bottom

Figure 4-35. (continued)

Table 4-5. SUMMARY OF AREA RELATIONSHIPS AND REQUIRED CONDUIT DIMENSIONS*

Ntype	Shape	Area	Required Dimensions, ft
1	Circular	(π/4)*(G1)**2	GEOM1 = Diameter
2	Rectangular	G1*G2	GEOM1 = Height GEOM2 = Width
3	Egg-shaped	$0.5105*(G1)^2$	GEOM1 = Height
4	Horseshoe	$0.829*(G1)^2$	GEOM1 = Height
5	Gothic	$0.655*(G1)^2$	GEOM1 = Height
6	Catenary	$0.703*(G1)^2$	GEOM1 = Height
7	Semielliptic	$0.785*(G1)^2$	GEOM1 = Height
8	Basket-handle	$0.786*(G1)^2$	GEOM1 = Height
9	Semi-circular	$1.27*(G1)^2$	GEOM1 = Height
10	Modified basket-handle	G2(G1 + (π/8)G2)	GEOM1 = Side Height GEOM2 = Width
11	Rectangular, triangular bottom	G2(G1 - G3/2)	GEOM1 = Height GEOM2 = Width GEOM3 = Invert height
12	Rectangular, round bottom	Θ = 2*ARSIN *(G2/(2G3)) Area = G1*G2 + (G3)**2/2 *(Θ - SIN(Θ))	GEOM1 = Side height GEOM2 - Width GEOM3 = Invert radius

---

*Refer to Figure 4-34 for definition of dimensions, G1, G2, and G3.

of an egg-shaped conduit of 3-foot depth is 0.5105 x 9 = 4.59 square feet. It is concluded that the conduit should be type 3 with GEOM1 = 3 feet.

Because of limits on the size of the computer program, it will usually not be possible to model every conduit in the drainage basin. Consequently, aggregation of individual conduits into longer ones will usually be the rule. Average slopes and sizes may be used provided that the flow capacity of the aggregate conduit is not significantly less than that of any portion of the real system. This is to avoid simulated surcharge conditions that would not occur in reality. In general, conduits should not be over 3,000 to 4,000 feet long in order to maintain reasonable routing accuracy. Conduit lengths should always be separated by manholes (or other non-conduit type elements). The conduit length should be measured from the center of the adjacent manholes.

Values of Manning's roughness may be known by engineers familiar with the sewer system. Otherwise, they may be estimated from tables in many engineering references (Refs. 9 and 12), as a function of the construction material and sewer condition. The value may be adjusted to account for losses not considered in the routing procedure (e.g., head losses in manholes or other structures, roots, obstructions). However, the flow routing is relatively insensitive to small changes in Manning's n.

Description of Non-Conduits

The sewer system consists of many different structures, each with its own hydraulic properties. Elements 16 through 22 are designed to simulate such structures. Data requirements for these elements were given in Table 4-4. Brief descriptions of these elements follow.

Manholes. No data are required for manholes except their numbers and upstream element numbers. Note that the number of upstream elements is limited to three. If more than three branches of the system should joint at a point, two manholes could be placed in series, allowing a total of five branches to joint at that point.

Lift Stations. The data requirements for lift stations were given in Table 4-4. It is assumed that the force main will remain full when the pump is not operating, resulting in no time delay in the flow routing (i.e., no time is required to fill the force main when the pump starts).

Type 18 and Type 21 Flow Dividers. The routing procedure through these elements is explained in the discussion of subroutine ROUTE. Typical uses are given below.

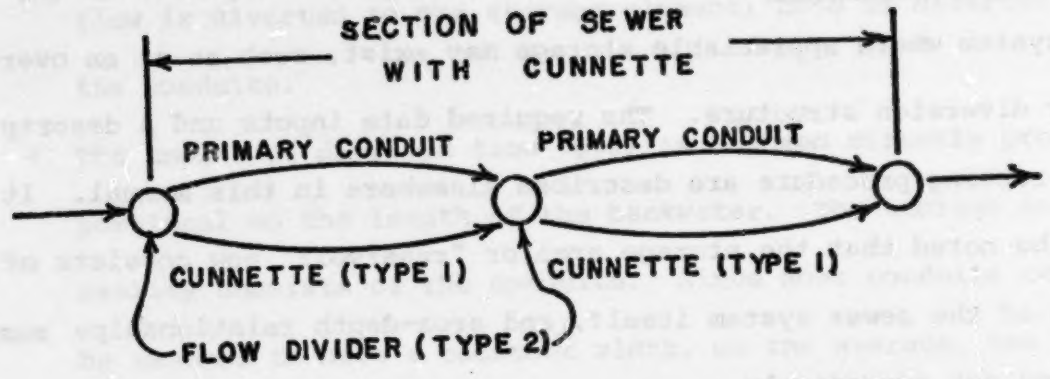
1. Simple Diversion Structure.

   A type 18 flow divider may be used to model a diversion structure in which none of the flow is diverted until it reaches a specified value (GEOM1). When the inflow is above this value, the non-diverted flow (Q01) remains constant at its capacity, GEOM1, and the surplus flow (Q02) is diverted.

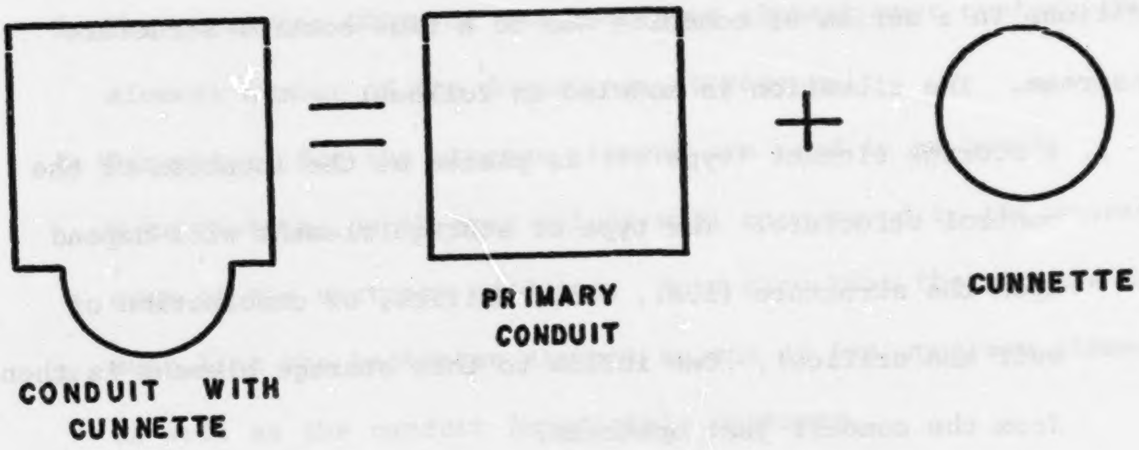
2. Cunnette Section.

A type 21 flow divider may be used to model a downstream cunnette section. The cunnette section is considered as a separate circular conduit to be placed parallel to the primary conduit as shown in Figure 4-36. In order to model the cunnette as a semi-circle, the separate circular conduit is given a diameter (GEOM1) so that its area will be twice that of the actual total cunnette flow area. (The distance, slope, and roughness will be the same as for the primary conduit). A type 21 flow divider is then the upstream element common to both conduits, as shown in Figure 4-36a. The program assigns a value of GEOM1 of the flow divider equal to half the full flow capacity of the circular pipe simulating the cunnette so that it has the hydraulic characteristics of a semi-circle). Any flow higher than GEOM1 will be diverted to the primary conduit. Note that the parameter GEOM3 of the flow divider will be the element number assigned to the cunnette section. Note further that the element downstream from the two parallel conduits must list them both as upstream elements.

Type 20 Flow Divider. This element is used to model a weir-type diversion structure in which a linear relationship can adequately relate the flow rate and the depth of flow at the weir. Input parameters were defined in Table 4-4. The operation of the element is explained in the discussion of subroutine ROUTE.


SECTION OF SEWER
WITH CUNNETTE
PRIMARY CONDUIT
PRIMARY CONDUIT
CUNNETTE (TYPE I)
CUNNETTE (TYPE I)
FLOW DIVIDER (TYPE 2)

a. SCHEMATIC OF HYPOTHETICAL FLOW DIVISION


CONDUIT WITH
CUNNETTE
PRIMARY
CONDUIT
CUNNETTE

b. SPLIT OF CONDUIT INTO PRIMARY CONDUIT AND CUNNETTE

Figure 4-36. CUNNETTE SECTION

The weir constant, incorporated into the variable ROUGH, can be varied to account for the type of weir. Typical values of the weir constant are 3.3 for a broad crested weir and 4.1 for a side weir (Ref. 13).

Type 19 - Storage Unit. This element may be placed anywhere in the sewer system where appreciable storage may exist, such as at an overflow or diversion structure. The required data inputs and a description of the routing procedure are described elsewhere in this manual. It should be noted that the storage area or "reservoir" now consists of a portion of the sewer system itself, and area-depth relationships must be worked out accordingly.

Backwater Element. This element may be used to model backwater conditions in a series of conduits due to a flow control structure downstream. The situation is modeled as follows:

1. A storage element (type 19) is placed at the location of the control structure. The type of storage element will depend upon the structure (i.e., weir, orifice, or combination of weir and orifice). One inflow to this storage element is then from the conduit just upstream.
2. If the water surface is extended horizontally upstream from the flow control structure at the time of maximum depth at the structure, it will intersect the invert slope of the sewer at a point corresponding to the assumed maximum length of backwater. The reach between this point and the structure may encompass several conduit lengths. A backwater element, type 22, is placed at this point of maximum backwater, in place of a manhole, for instance.

3. The backwater element then diverts flow directly into the storage element depending upon the volume of water (and hence, the length of backwater) in the storage element. If the backwater extends all the way to the backwater element, the total flow is diverted to the storage element; none is diverted to the conduits.
4. The amount of diverted flow (Q01) is assumed directly proportional to the length of the backwater. The storage area in reality consists of the conduits. Since most conduits can be assumed to have a constant width, on the average, the backwater length is assumed proportional to the square root of the current storage volume, obtained from the storage routine.
5. The parameter GEOM3 of the backwater element must contain the element number of the downstream storage unit.
6. Parameters for the storage element are read in as usual. Note that the depth-area values will correspond to the storage area of the upstream conduits. Note also that the storage unit must list the backwater element as one of its upstream elements, as well as the conduit immediately upstream.
7. At each time-step, the backwater element computes the ratio of current to maximum storage volume in the downstream storage element. Call this ratio r.

   Then Q01 = QI r**0.5

   and Q02 = QI-Q01

where Q01 = Flow directly into storage unit

Q02 = Flow into intermediate conduits

QI = Inflow to backwater element.

Step 3 - Input Data and Computational Controls. The basic input data, hydrographs and pollutographs are generated outside of the Transport Model. However, certain operational controls are available within Transport.

Choice of Time-Step

The size of the time-step, DT, may be chosen to coincide with the spacing of the ordinates of the inflow hydrographs and pollutographs. However, it should not be greater than five minutes.

Choice of Number of Time-steps

The total number of time-steps should not be less than the number used in the Runoff Block nor greater than 150.

Choice of Number of Iterations

The purpose of iterations in the computations is to reduce flow oscillations in the output. The flatter pipe slopes (less than 0.001 ft/ft) require iterations of the flow routing portion of the Transport Model to help dampen these oscillations. Four iterations have proven to be sufficient in most cases.

Internal Storage Model

Use of the internal storage routine involves 5 basic steps.

Step 1 - Call. The internal storage routine is called by subroutine TRANS when element type 19 is specified. No more than two locations may be specified in a single run.

Step 2 - Storage Description: Part 1. Describe the storage unit mode (in-line); construction (natural, manmade and covered, manmade and uncovered); and type of outlet device (orifice, weir, or pumped).

Step 3 - Output. Select output and computational options according to the following:

1. Flow routing by plug flow or complete mixing.
2. Complete printout or supressed.
3. Costs estimated or costs supressed.

Step 4 - Storage Description: Part 2. Describe the basin flood depth and geometry. Describe design parameters of outlet control. Describe initial conditions in basin.

Step 5 - Unit Costs. Specify unit costs to be used if cost output is desired.

The sequence of cards and choices (Steps 2-5) are repeated for each storage basin location.

Infiltration Model

Effective use of the Infiltration Model requires estimates of its component flows, namely:

DINFIL = Dry weather infiltration

RINFIL = Wet weather infiltration

SINFIL = Melting residual ice and snow

GINFIL = Groundwater infiltration.

Step 1 - Determine Groundwater Condition. If the groundwater table is predominently above the sewer invert, all infiltration is attributed to this source. In this case an estimate of the total infiltration is made directly (in cfs for the total drainage basin) and read in on a data card. This card followed by two blank cards would complete the infiltration data input. If the groundwater table is not predominently above the sewer invert, proceed to Step 2.

Step 2 - Build Up Infiltration from Base Estimates. From measurements, historical data, or judgment, provide estimates of DINFIL and RINFIL. In this case GINFIL must be set equal to 0.0. Next, provide the control parameters: the day the storm occurs (a number from 1 to 365 starting with July 15 as day 1), the peak residual moisture (see Example 2 below), and the average pipe length (in feet). Finally, read in the 12 monthly degree-day totals taken from Appendix A or a local source.

Dry Weather Flow Model

Use of the Dry Weather Flow model involves 3 basic steps.

Step 1 - Establishing Subareas. Establishment of subareas constitutes the initial step in applying subroutine FILTH. Both detail of input data and assumptions made in developing FILTH impose constraints on the type, size, and number of subareas. However, most important in subarea establishment is the type of estimating data available. An upper limit of 200 acres per subarea is assumed in the following discussion. This is a somewhat arbitrary limit based in part on previous verification results from FILTH.

Subareas should be located and sized to utilize existing sewer flow measurements taken within the drainage basin. These measurements should be recent and of sufficient duration to provide a current average sewage flow value for the period of time during which simulation is to proceed. Daily and hourly flow variation should be compared to assumed values as described earlier in the text. A gaging site with less than 200 acres contributing flow provides a very convenient data input situation. A subarea should be established upstream from the gage with average sewage flow tabulated as SEWAGE for that subarea.

If metered water use is to be used to estimate sewage flow, subareas should be located to coincide with meter reading zones or other zones used by the water department that simplify data takeoff. Since water use would be used to estimate sewage flow, average winter readings should be used to minimize the effects of lawn sprinkling and other summer uses.

If neither gaging nor metered water use are input, sewage estimates must be made. Subareas should then be established to yield appropriate input data for the residential estimating equations in FILTH. Zero sewage flow is assumed from commercial, industrial, and parkland subareas for which estimates or measurements of SAQPF are not given. Since KLAND and VALUE are the significant variables in estimating subarea sewage flow, subareas should be located and sized to include land with uniform land use and property valuation. To utilize existing census data, subarea boundaries should be made to coincide with census tract boundaries.

Criteria for establishing subareas are listed in the following summary:

1. Subareas in general should:
    - a. Be less than or equal to 200 acres in size
    - b. Be less than or equal to 150 in number
    - c. Conform to the branched pipe network.
2. Subareas should be established to employ any existing sewer flow measurements.
3. Subareas for which metered water use is used to estimate sewage flow should be compatible with meter reading zones.
4. Residential subareas for which estimated water use is used to estimate sewage flow should:
    - a. Be uniform with respect to land use
    - b. Be uniform with respect to dwelling unit valuation
    - c. Coincide with census tracts.

Step 2 - Collection of Data. Other than the establishment of measured data described hereinbefore, the primary data source is the U.S. Bureau of the Census for census tract information. This source provides readily available data on population distribution, family income, and the number and relative age of dwelling units. City records, aerial photographs, and on-site inspection may be necessary to define land use activities, process flows, and dwelling density variations within tracts.

Step 3 - Data Tabulation. Once subareas have been established, several alternatives exist regarding data tabulation. An identification number KNUM should be given to each subarea prior to data takeoff. However, once KNUM's have been established, corresponding INPUT manhole numbers are selected from a previously numbered schematic diagram of the trunk sewer. This numbered schematic serves as the mechanism to coordinate runoff, infiltration, and sewage inputs. Refer to the subroutine TRANS discussion for additional information about the numbered schematic. If water use estimates are necessary, land use should be determined from city zoning maps and the previously tabulated values for KLAND.

ADWF should be tabulated as average drainage basin sewage flow. As with ADWF, SEWAGE should be averaged from flow data for the appropriate month, season, or year. ADWF, SAQPF, or SEWAGE may be obtained from routine or specific gaging programs done by the city, consulting engineers, or other agencies. SAQPF may be estimated for commercial and industrial areas using water use coefficients. Also, SAQPF and WATER may be determined for all land use categories from water meter records.

BLANK PAGE

Table 4-6. TRANSPORT BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	16I5	5	Number of sewer cross-sectional shapes, in addition to the 12 program-supplied for which element routing parameters are to follow (maximum value = 3).	NKLASS	0
		10	Control parameter for printing out routing parameters for all shapes, i.e.,	KPRINT	0
			KPRINT = 0 to suppress printing,		
			KPRINT = 1 to allow printing.		
			DELETE CARD GROUPS 2 TO 10 IF NKLASS = 0.		
2			Name of user-supplied shapes.	NAME	
	20A4	1-16	16-letter name of shape 1.	NAME(I,13)	none
		17-32	16-letter name of shape 2.	NAME(I,14)	none
		33-48	16-letter name of shape 3.	NAME(I,15)	none
3			Number of values of DNORM to be supplied (maximum value = 51, minimum value = 2).	NN	
	16I5	4-5	Number of values for shape 1.	NN(13)	none
		9-10	Number of values for shape 2.	NN(14)	none
		14-15	Number of values for shape 3.	NN(15)	none
4			Number of values of ANORM or QNORM to be read (maximum value = 51, minimum value = 2).	MM	
	16I5	4-5	Number of values for shape 1.	MM(13)	none
		9-10	Number of values for shape 2.	MM(14)	none
		14-15	Number of values for shape 3.	MM(15)	none
5			Value of A/A_f* corresponding to the maximum Q/Q_f** value for each shape.	ALFMAX	
	8F10.5	1-10	A/A_f value for shape 1.	ALFMAX(13)	none
		11-20	A/A_f value for shape 2.	ALFMAX(14)	none
		21-30	A/A_f value for shape 3.	ALFMAX(15)	none

---

*A/A_f is the cross-sectional flow area divided by the cross-sectional flow area of the pipe running full.

**Q/Q_f is the flow rate of the flow divided by the flow rate of the conduit flowing full.

NOTE: All non-decimal numbers must be right-justified.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
6			Maximum Q/Q_f value for each shape.	PSIMAX	
	8F10.5	1-10	Maximum Q/Q_f value for shape 1.	PSIMAX(13)	none
		11-20	Maximum Q/Q_f value for shape 2.	PSIMAX(14)	none
		21-30	Maximum Q/Q_f value for shape 3.	PSIMAX(15)	none
7			Factor used to determine full flow area for each shape, i.e., for use in equation $AFULL = AFACT(GEOM1)^2$.	AFACT	
	8F10.5	1-10	Factor for shape 1.	AFACT(13)	none
		11-20	Factor for shape 2.	AFACT(14)	none
		21-30	Factor for shape 3.	AFACT(15)	none
8			Factor used to determine full flow hydraulic radius for each shape, i.e., for use in equation. RADH = RFACT(GEOM1).	RFACT	
	8F10.5	1-10	Factor for shape 1.	RFACT(13)	none
		11-20	Factor for shape 2.	RFACT(14)	none
		21-30	Factor for shape 3.	RFACT(15)	none
			REPEAT CARD GROUP 9 FOR EACH ADDED SHAPE.		
9			Input of tabular data (area of flow, A, divided by area of conduit, A_f, (A/A_f)) for each added shape corresponding to the equal divisions of the conduit as given by NN on card group 3.	DNORM	
	8F10.5	1-10	First value for A/A_f for shape 1.	DNORM(I,1)	none
		11-20	Second value for A/A_f for shape 1.	DNORM(I,2)	none
		⋮		⋮	
			Last value of A/A_f for shape 1.	DNORM(I,NN(I))	none
			(Total of NN(13)/8 + NN(14)/8 + NN(15)/8 data cards.)		
			REPEAT CARD GROUP 10 FOR EACH ADDED SHAPE.		
10			Input of tabular data (flow rate of flow, Q, divided by the flow rate of the conduit running full, Q_f, (Q/Q_f)) for each added shape corresponding to the equal divisions of the conduit as given by MM on card group 4.	QNORM	
	8F10.5	1-10	First value of Q/Q_f for shape 1.	QNORM	none
		11-20	Second value of Q/Q_f for shape 1.	QNORM(I,2)	none
		⋮		⋮	
			Last value for Q/Q_f for shape 1.	QNORM(I,MM(I))	none
			(Total of MM(13)/8 + MM(14)/8 + MM(15)/8 data cards.)		

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
11	20A4		Title card containing a one-line heading to be printed above output. A numeral 1 should be placed in card column 1 for neat spacing print out.	TITLE	none
12			Execution control data.		
	16I5	3-5	Total number of sewer elements (maximum = 150).	NE	
		8-10	Total number of time-steps (maximum = 150).	NDT	none
		14-15*	Total number of non-conduits into which there will be input hydrographs and pollutographs (maximum = 60, minimum = 1).	NINPUT	none
		19-20	Total number of non-conduit elements at which input hydrographs and pollutographs are to be printed out (maximum = 10, minimum = 1).	NNYN	none
		24-25	Total number of non-conduit elements at which routed hydrographs and pollutographs are to be printed out (maximum = 10, minimum = 1).	NNPE	none
		30**	Total number of non-conduit elements at which flow is to be transferred to the Receiving Water Model by tape (maximum = 5, minimum = 1).***	NOUTS	none
		35	Control parameter for program-generated error messages concerning irregularities occurring in the execution of the flow routing scheme, i.e., NPRINT = 0 to suppress messages, NPRINT = 1 to print messages from ROUTE, NPRINT = 2 to print messages from ROUTE and TRANS.	NPRINT	0
		40	Total number of pollutants being routed (minimum =1, maximum = 4).	NPOLL	none
		45	Total number of iterations to be used in routing routine (4 recommended).	NITER	4
13			Execution control data.		
	8F10.5	1-10	Size of time-step for computations (sec).	DT	none
		11-20	Allowable error for convergence of iterative methods in routing routine (0.0001 recommended).	EPSIL	0.0001
		21-30	Total number of days (dry weather days) prior to simulation during which solids were not flushed from the sewers.	DWDAYS	none

---

*Must be the same as in the RUNOFF Block (NSAVE).

**These are the only points that can be plotted by subroutine GRAPH after being routed by TRANSPORT.

***A maximum of 37 may be transferred to subroutine GRAPH.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
14			Execution control data.		
	16I5	5	Control parameter specifying means to be used in transferring inlet hydrographs, i.e., NCNTRL = 1, normal transfer by tape or disk, NCNTRL = 0, special transfer requiring additional input specifications.	NCNTRL	0
		10	Control parameter in estimating groundwater infiltration inflows, i.e., NINFIL = 1, infiltration to be estimated (subroutine INFIL called), NINFIL = 0, infiltration not estimated (INFIL not called and corresponding data omitted).	NINFIL	0
		15	Control parameter in estimating sanitary sewage inflows, i.e., NFILTH = 1, sewage inflows to be estimated (subroutine FILTH called), NFILTH = 0, sewage inflows not estimated (FILTH not called and corresponding data omitted).	NFILTH	0
		20	Control parameter concerning printed output, i.e., JPRINT = 1, flows and concentrations printed out in tabular form, JPRINT = 0, flows and concentration not printed or plotted.	JPRINT	0
			REPEAT CARD GROUP 15 FOR EACH NUMBERED SEWER ELEMENT		
15			Sewer element data.		
	5I4	1-4	External element number. No element may be labeled with a number greater than 1000, and it must be a positive numeral (maximum value = 1000).	NOE	none
			External number(s) of upstream element(s). Up to three are allowed. A zero denotes no upstream element (maximum value = 1000).		
		5-8	First of three possible upstream elements.	NUE(1)	none

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		9-12	Second of three possible upstream elements.	NUE(2)	none
		13-16	Third of three possible elements.	NUE(3)	none
		17-20	Classification of element type. Obtain value from Table 4-3.	NTYPE	16
			THE FOLLOWING VARIABLES ARE DEFINED BELOW FOR CONDUITS ONLY. REFER TO TABLE 4-4 FOR REQUIRED INPUT FOR NON-CONDUITS.		
	7F8.3	21-28	Element length for conduit (ft).	DIST	none
		29-36	First characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition.	GEOM1	0.0
		37-44	Invert slope of conduit (ft/100 ft).	SLOPE	0.1
		45-52	Manning's roughness of conduit.	ROUGH	0.013
		53-60	Second characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition. (Not required for some conduit shapes.)	GEOM2	none
		61-68	Number of barrels for this element. The barrels are assumed to be identical in shape and flow characteristics.	BARREL	1.0
		69-76	Third characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition. (Not required for some conduit shapes.)	GEOM3	none
********************************			CARDS 16 THROUGH 26 ARE DATA INPUT FOR INTERNAL STORAGE. (NTYPE = 19). OMIT THESE DATA CARDS IF INTERNAL STORAGE IS NOT DESIRED.	************************	
			REPEAT STORAGE MODEL DATA FOR EACH STORAGE ELEMENT (MAXIMUM = 2).		
16			Storage unit data card.		
	10I5	1-5*	Storage mode parameter. = 1 In-line storage.	ISTMOD	none
		6-10	Storage type parameter. = 1 Irregular (natural) reservoir. = 3 Geometric (regular) uncovered reservoir.	ISTTYP	none
		11-15	Storage outlet control parameter. = 1 Gravity with orifice center line at zero storage tank depth. = 2 Gravity with fixed weir. = 6 Existing fixed-rate pumps. = 9 Gravity with both weir and orifice.	ISTOUT	none

---

*Must be set equal to one since other storage mode parameters are not programmed.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
17			Computation/print control card.		
	3I10	1-10	Pollutant parameter. = 0 No pollutants (hydraulics only). = 1 Perfect plug flow through basin. = 2 Perfect mixing in basin.	IPOL	none
		11-20	Print control parameter. = 0 No print each time-step. = 1 Print each time-step in storage.	IPRINT	none
		21-30	Cost computation parameter. = 0 No cost computations. = 1 Costs to be computed.	ICOST	none
18			Reservoir flood depth data card.		
	F10.2	1-10	Maximum (flooding) reservoir depth(ft).	DEPMAX	none
			INCLUDE EITHER CARD GROUP 19 OR 20, NOT BOTH.		
			INCLUDE CARD GROUP 19 ONLY IF ISTTYP ON CARD 16 HAS THE VALUE 1.		
19			Reservoir depth-area data card (4(F10.2, F10.0)).		
	F10.2	1-10	A reservoir water depth (ft).	ADEPTH(1)	none
	F10.0	11-20	Reservoir surface area corresponding to above depth(sq ft).	AASURF(2)	none
	⋮			⋮	
	F10.2	61-70	A reservoir water depth(ft).	ADEPTH(4)	none
	F10.0	71-80	Reservoir surface area corresponding to above depth(sq ft). (NOTE: The above pair of variables is repeated 11 times, 4 pairs per card.)	AASURF(4)	
			INCLUDE CARD 20 ONLY IF ISTTYP ON CARD 16 HAS THE VALUE 3.		
20			Reservoir dimensions data card.		
	2F10.0	1-10	Reservoir base area (sq ft)	BASEA	none
		11-20	Reservoir base circumference (ft)	BASEC	none
	F10.5	21-30	Cotan of sideslope (horizontal/vertical).	COTSLO	none

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			INCLUDE ONLY ONE OF THE OUTLET DATA CARDS 21, 22, 23, or 24.		
			INCLUDE CARD 21 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 1.		
21			Orifice outlet data card.		
	F10.3	1-10	Orifice outlet area x discharge coefficient (sq ft).	CDAOUT	none
			INCLUDE CARD 22 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 2.		
22			Weir outlet data card.		
	2F10.3	1-10	Weir height (ft) above depth = 0.	WEIRHT	none
		11-20	Weir length (ft).	WEIRL	none
			INCLUDE CARD 23 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 6.		
23			Pump outlet data card.		
	3F10.3	1-10	Outflow pumping rate (cfs).	QPUMP	none
		11-20	Depth (ft) at pump startup.	DSTART	none
		21-30	Depth (ft) at pump shutdown (DSTOP > 0.0).*	DSTOP	none
			INCLUDE CARD 24 ONLY IF ISTOUT HAS THE VALUE 9.		
24			Weir and orifice outlet data card.		
	8F10.5	1-10	Weir height above depth = 0 (ft).	WEIRHT	none
		11-20	Weir length (ft).	WEIRL	none
		21-30	Orifice outlet area x discharge coefficient (sq ft).	CDAOUT	none
		31-40	Orifice centerline elevation above zero depth (ft).	ORIFHT	none
25			Initial conditions data card.		
	2F10.2	1-10	Storage (cf) at time zero.	STORO	none
		11-20	Outflow rate (cfs) at time zero.	QOUTO	none

*DSTOP must equal or be greater than the level in storage that contains enough volume to handle the pumping rate, QPUMP, for one time-step.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			CARD 26 MUST BE INCLUDED: IT MAY BE BLANK IF ICOST ON CARD 17 HAS THE VALUE 0.		
26			Cost data card.		
	F10.2	1-10	$/cy for storage excavation.	CPCUYD	none
	2F10.0	11-20	$/acre for storage land.	CPACRE	none
		21-30	$/pump station with related structures.	CPS	none
			******************************** END OF INTERNAL STORAGE DATA CARDS. **************************		
			TO BE READ FROM TAPE (unformatted) IF NCNTRL = 1.		
A*			Description of following inlet hydrographs. (160 character string)	TITLE(I)	none
B*			Control variable.		
			Total number of time-steps in RUNOFF.	NDUMI	none
			Total number of inlet hydrographs.	NINPUT	none
			Total number of pollutants.	NPOLL	none
			Time-step length (sec) in RUNOFF.	NDUM2	none
			Clock time for beginning of rain (sec).	TZERO	none
C*			Non-conduit element numbers into which hydrographs and pollutographs (transferred from the Runoff Model) enter the sewer system. These must be in the order in which hydrograph and pollutograph ordinates appear at each time-step.	NORDER(I)	none
27**			List of external non-conduit element numbers at which outflows are to be transferred to Receiving Water Model (minimum number of elements specified = 1, maximum number = 5).	JN	
	16I5	1-5	First element number.***	JN(1)	none
		6-10	Second element number.***	JN(2)	none
		⋮			
			Last element number.***	JN(NOUTS)	none
28			List of external non-conduit element numbers at which input hydrographs and pollutographs are to be stored and printed out (minimum number of elements specified = 1, maximum number = 10).	NYN	
	16I5	1-5	First input location number.	NYN(1)	none
		6-10	Second input location number.	NYN(2)	none
		⋮			
			Last input location number.	NYN(NNYN)	none

---

*Information that is transferred from RUNOFF Block, data cards are not required.

**Only these element numbers can be plotted by subroutine GRAPH.

***Element numbers transferred to the Receiving Water Block must be numbered less than 100.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
29			List of external non-conduit element numbers at which output hydrographs and pollutographs are to be stored and printed out (minimum number of elements specified = 1, maximum number = 10).	NPE	
	16I5	1-5	First output location number.	NPE(1)	none
		6-10	Second output location number.	NPE(2)	none
		⋮		⋮	
			Last output location number	NPE(NNPE)	none
			IF SUBROUTINE INFIL IS TO BE CALLED (NINFIL = 1), INSERT CARDS 30 THROUGH 32, OTHERWISE OMIT.		
30			Estimated infiltration.		
	10F8.1	1-8	Base dry weather infiltration (gpm).	DINFIL	0.0
		9-16	Groundwater infiltration (gpm).	GINFIL	0.0
		17-24	Rainwater infiltration (gpm).	RINFIL	0.0
31			Control parameters.		
	I5	3-5	Day of estimate.	NDYUD*	none
	6F8.1	6-13	Peak residual moisture (gpm).	RSMAX	0.0
		14-21	Average joint distance (ft).	ULEN	6.0
32			Monthly degree-days.	NDD	
	16I5	1-5	July degree-days.	NDD(1)	none
		6-10	August degree-days.	NDD(2)	none
		⋮		⋮	⋮
		56-60	June degree-days.	NDD(12)	none
			IF SUBROUTINE FILTH IS TO BE CALLED (NFILTH = 1), INSERT CARD GROUPS 33 TO 44, OTHERWISE OMIT.		
33			Factors to correct yearly average sewage flows to daily averages by accounting for daily variations throughout a typical week.		
	7F10.0	1-10	Flow correction for Sunday.	DVDWF(1)	1.0
		11-20	Flow correction for Monday.	DVDWF(2)	1.0
		⋮		⋮	
		61-70	Flow correction for Saturday.	DVDWF(7)	1.0

---

*Day one is July 15.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
34			Factors to correct BOD yearly averages to daily averages.		
	7F10.0	1-10	BOD correction for Sunday.	DVBOD(1)	1.0
		⋮			⋮
		61-70	BOD correction for Saturday.	DVBOD(7)	1.0
35			Factors for correction of yearly SS averages to daily averages.		
	7F10.0	1-10	SS correction for Sunday.	DVSS(1)	1.0
		⋮			⋮
		61-70	SS correction for Saturday.	DVSS(7)	1.0
36			Factors to correct daily average sewage flow to hourly averages by accounting for hourly variations throughout a typical day (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVDWF(1)	1.0
		⋮			⋮
		1-10	8 a.m. to 9 a.m. factor (second card).	HVDWF(9)	1.0
		⋮			⋮
		1-10	4 p.m. to 5 p.m. factor (third card).	HVDWF(17)	1.0
37			Factors for BOD hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVBOD(1)	1.0
		⋮			⋮
		71-80	11 a.m. to midnight factor (third card).	HVBOD(24)	1.0
38			Factors for SS hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVSS(1)	1.0
		⋮			⋮
		71-80	11 a.m. to midnight factor (third card).	HVSS(24)	1.0
			INCLUDE ONLY WHEN 3 POLLUTANTS ARE SPECIFIED.		
39			Factors for E. coli hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVCOLI(1)	1.0
					⋮
		71-80	11 a.m. to midnight factor (third card).	HVCOLI(24)	1.0

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
40			Study area data.		
	6I5	1-5	Total number of subareas within a given study area in which sewage flow and quality are to be estimated.	KTNUM	none
		6-10	Indicator as to whether study area data, such as treatment plant records, are to be used to estimate sewage quality, i.e., KASE = 1, yes, KASE = 2, no.	KASE	1
		11-15	Total number of process flows within the study area for which data are included in one of the following card groups.	NPF	0
		16-20	Number indicating the day of the week during which simulation begins (Sunday = 1).	KDAY	0
		21-25	Number indicating the hour of the day during which simulation begins (1 a.m. = 1).	KHOUR	0
		26-30	Number indicating the minute of the hour during which simulation begins.	KMINS	0
	2F5.1	31-35	Consumer Price Index.	CPI	109.5
		36-40	Composite Construction Cost Index.	CCCI	103.0
	F10.3	41-50	Total population in all areas (thousands).	POPULA	none
			IF KASE = 1, INCLUDE CARD GROUPS 41, 42 AND 43.		
41			Average study area data.		
	3F10.0	1-10*	Total study area average sewage flow, i.e., from treatment plant records(cfs).	ADWF	0.0
		11-20	Total study area average BOD (mg/L).	ABOD	none
		21-30	Total study area average SS (mg/L).	ASUSO	none
	E10.2	31-40	Total coliforms (MPN/100 ml).	ACOCI	none
42			Categorized study area data.		
	8F8.0	1-8	Total study area from which ABOD and ASUSO were taken (acres).	TOTA	none
		9-16	Total contributing industrial area (acres).	TINA	none
		17-24	Total contributing commercial area (acres).	TCA	none

---

*If ADWF = 0.0, then total BOD, SS, and COLI will = 0.0.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		25-32	Total contributing high income (above $15,000) residential area (acres).	TRHA	none
		33-40	Total contributing average income (above $7,000 but below $15,000) residential area (acres).	TRAA	none
		41-48	Total contributing low income (below $7,000) residential area (acres).	TRLA	none
		49-56	Total area from the above three residential areas that contribute additional waste from garbage grinders (acres).	TRGGA	none
		57-64	Total park and open area within the study area (acres).	TPOA	none
			IF PROCESS FLOW DATA ARE AVAILABLE (NPF NOT EQUAL 0 AND KASE = 1), REPEAT CARD GROUP 43 FOR EACH PROCESS FLOW.		
43			Process flow characteristics.		
	I5	1-5	External manhole number into which flow is assumed to enter (maximum value = 150, minimum value = 1).	INPUT	none
	6F10.3	6-15	Average daily process flow entering the study area system (cfs).	QPF	none
		16-25	Average daily BOD of process flow (mg/L).	BODPF	none
		26-35	Average daily SS of process flow (mg/L).	SUSPF	none
			REPEAT CARD GROUP 44 FOR EACH OF THE KTNUM SUBAREAS.		
44			Subarea data.		
	2I3	1-3	Subarea number.	KNUM	none
		4-6	External number of the manhole into which flow is assumed to enter for subarea KNUM (maximum value = 150, minimum value = 1).	INPUT	none
	3I1	7	Predominant land use within subarea.	KLAND	none
		8	Parameter indicating whether or not water usage within subarea KNUM is metered. METHOD = 1, metered water use, METHOD = 2, incomplete or no metering.	METHOD	2
		9	Parameter indicating units in which water usage estimates (WATER) are tabulated. KUNIT = 0, thousand gal./mo, KUNIT = 1, thousand cf/mo.	KUNIT	0

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
	13F5.1	10-14	Measured winter water use for subarea KNUM in the units specified by KUNIT (not required).	WATER	none
		15-19	Cost of the last thousand gal. of water per billing period for an average consumer within subarea KNUM (cents/1,000 gal.) (not required).	PRICE	none
		20-24	Measured average sewage flow from the entire subarea KNUM (cfs) (not required).	SEWAGE	none
		25-29	Total area within subarea KNUM (acres) (maximum = 200).	ASUB	none
		30-34*	Population density within subarea KNUM (population/acre).	POPDEN	none
		35-39*	Total number of dwelling units within subarea KNUM.	DWLNGS	10.0/ac.
		40-44*	Number of people living in average dwelling unit within subarea KNUM.	FAMILY	3.0
		45-49*	Market value of average dwelling unit within subarea KNUM (thousands of dollars).	VALUE	20.0
		50-54*	Percentage of dwelling units possessing garbage grinders within subarea KNUM.	PCGG	none
		55-59**	Total industrial process flow originating within subarea KNUM (cfs).	SAQPF	0.0
		60-64	BOD contributed from industrial process flow originating within subarea KNUM (mg/L).	SABPF	none
		65-69	SS contributed from industrial process flow originating within subarea KNUM (mg/L).	SASPF	none
		70-74	Income of average family living within	XINCOM	VALUE/2.5
	I2	75-76	MSUBT = 0, subtotals not made, MSUBT = 1, subtotal made.	MSUBT	0
			END OF FILTH DATA CARDS.		

---

*Not required if KLAND greater than 2.

**If SAQPF = 0.0, then DWBOD and DWSS will be zero for Land Use 4 (i.e., for industrial flows to be considered KLAND must equal 4).

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			TO BE READ FROM TAPE AT EACH TIME-STEP (unformatted).		
D*			Time-step number.	DTIM	none
			Runoff at each inlet point (cfs).	RNOFF(I)	none
			Pollutant rates for each pollutant at each inlet point (lb/min).	PLUTO(I,J)	none
			i.e., for each record.	DTIM RNOFF(1) ⋮ RNOFF(NINPUT) PLUTO(1,1) ⋮ PLUTO(NINPUT,1) ⋮	
			FOR GRAPHING TRANSPORT OUTPUT, CALL GRAPH SUBROUTINE THROUGH THE EXECUTIVE BLOCK.		
			END OF TRANSPORT BLOCK DATA CARDS.		

---

*Information that is transferred from RUNOFF Block; data cards not required.

Table 4-7. TRANSPORT BLOCK VARIABLES

Variable Name	C*	Description	Units
A	C	Cross-sectional areas of flow	sq ft
AA		Cross-sectional areas of flow	sq ft
AAA	C	Flow depth computational variable	
AASURF		Surface area (data array member)	sq ft
AC		Area computational variable	
ABOD		Average BOD concentration measured in sewer or at treatment facility	mg/L
ACOLI		Total coliforms	MPN/100 ml
ADEPTH		Depth (data array member)	ft
ADWF		Average measured DWF	cfs
AF		Cross-sectional area of conduit	sq ft
AFACT	C	Factor to calculate AFULL	
AFULL	C	Full flow area for conduits	sq ft
AINFIL		Total infiltration within drainage basin	cfs
ALF	C	Value of A/A_f corresponding to Q/Q_f value	
ALFMAX	C	Value of A/A_f corresponding to maximum Q/Q_f value	
ALM		Computational variable associated with conduit area	
ALPHA		Normalized area flow, A/A_f	
ANORM	C	Normalized depths, D/D_f, corresponding to A/A_f	
AO2DT2		Routing parameter (data array member)	
APLAN	C	Land area requirement	sq ft
AQQ		Average computed infiltration	cfs
AREAF		Flow area of given flow rate in conduit	sq ft
ARG		Cotangent of angle which is formed from radius and wetted surface	
ASUB		Total area within subarea KNUM	acres
ASUSO		Average SS concentration measured in sewer or at treatment facility	mg/L
ATERM	C	Variable used to calculate area of a conduit, area flow/area full	
A1		Normalized depth of conduit upstream, A/A_f	ft
A1BOD		Average weighted BOD	lb/day/cfs
A1COLI		Average number of coliform bacteria	MPN/day/cfs
A1SS		Average weighted SS	lb/day/cfs
A2		Normalized depth of conduit downstream, A/A_f	ft
BARREL	C	Total number of barrels in each conduit	
BASEA		Base area (geometric basin)	sq ft
BASEC		Base circumference (geometric basin)	ft
BDEPTH	C	Depth (array member)	ft
BLANK	C	Supercritical flow indicator	
BODCON		Computed BOD concentration	mg/L
BODCOT		BOD outflow concentration	mg/L
BODIN	C	BOD input to storage element	lb/DT
BODOUT	C	BOD output from storage element	lb/DT
BODPF		Average BOD of a process flow	mg/L
BSTOR	C	Maximum storage capacity of storage element	cf

C* = Variable names shared in common blocks.

Table 4-7 (continued)

Variable Name	C*	Description	Units
CATH	C	Flow depth computation variable	
CATHY		Flow depth variable used in computing the hydraulic radius	
CCCI		Composite construction cost index	
CDAOUT		Orifice area x discharge coefficient	sq ft
CF		Correction factor to weight sewage strength	
CF2		Correction factor for DWF	
CLAND	C	Cost of land	$
COSTSLO		Basin sideslopes cotangent	ft/ft
CPACRE	C	Unit cost of land	$/acre
CPCUYD	C	Unit cost of excavation	$/cy
CPI		Consumer Price Index	
CPOLL	C	Pollutant concentrations	lb/cf
CPS	C	Pumping station and structure cost	$/ps
CRITD		Critical settling diameter of particles undergoing deposition in conduits	mm
CSTOR	C	Cost of excavation for storage	$
CTOTAL	C	Total cost	$
CUMIN		Cumulative water inflow	cf
CUMOUT	C	Cumulative water outflow	cf
C1	C	Flow routing variable	variable
C1BOD		Computed BOD total after deducting process flows	lb/day
C1DT		Time-step	days
C1DWF		Total DWF less infiltration	cfs
C11		Normalized flow-area computational variable	
C2		Negative value of normalized flow rate	
C2BOD		Computed BOD total further corrected for weighting effects	lb/day
C2DWF		C1DWF less process flows	cfs
C2SS		Weighted SS strengths according to subarea	lb/day
D		Computational variable used in subroutine NEWTON	
DALPHA		Increment for normalized area data	
DD		Wetted depth of the modified element cross-section area, i.e., basket-handle conduit and rectangular with triangular bottom	
DDEPTH		Depth increment	ft
DDWF		Daily adjusted sewage inflows, ADWF	cfs
DELQ		Incremental difference of the flows between each time-step	cfs
DEPMAX	C	Maximum flooding depth of reservoir	ft
DEPTH		Water depth of reservoir	ft
DEPTHL		Depth of reservoir for the previous time-step	ft
DETENT	C	Reservoir plug flow detention time	sec
DH		Computation variable used in determining the flow over a flow divider	
DIAM		Diameter of circular pipe	ft

Table 4-7 (continued)

Variable Name	C*	Description	Units
DINFIL		Dry weather infiltration	gpm
DIST	C	Conduit length	ft
DNORM	C	Normalized depths of flow	
DPSI		Derivative of Q/Q_f with respect to A/A_f	
DPSI		Name of subroutine	
DSTART	C	Depth at the pump startup	ft
DSTOP	C	Depth at pump shutdown	ft
DT	C	Size of time-step	sec
DTIM		Time on input tape from RUNOFF	sec
DTMORE	C	Extra time-step needed to pump dry	
DTON	C	Number of time-steps pumped	
DTPUMP	C	Total time-steps to pump dry	
DUMDEP	C	Dummy depth used in internal storage reservoir calculations	ft
DUMSTR	C	Dummy storage volume used in internal storage reservoir calculations	cf
DUMY1		Corrected hourly DWF	cfs
DUMY2		Corrected hourly BOD concentration	lb/sec
DUMY3		Corrected hourly SS concentration	lb/sec
DUMY4		Corrected hourly concentration of fourth pollutant	(not yet programmed)
DUMY5		Corrected hourly coliform concentration	MPN/sec
DV		The change in flow velocity between two succeeding flow routing iterations	
DVBOD	C	Daily BOD variation factor	
DVDWF	C	Daily sewage flow variation factor	

Variable Name	C*	Description	Units
DVSS	C	Daily SS variation factor	
DWBOD		BOD of DWF of each subarea	lb/sec/DT
DWCOLI		Coliform load of DWF in each subarea	MPN/100 mL
DWDAYS		Total number of antecedent dry days	days
DWF		Dry weather flow	cfs
DWLNGS		Total number of dwelling units within subarea KNUM	
DWLOAD		Name of subroutine	
DWSS		SS of DWF in each subarea	lb/sec/DT
DW1BOD		DWF BOD in each subarea for each time-step	lb/DT
DW1SS		DWF SS in each subarea for each time-step	lb/DT
DXDT	C	Length of conduit divided by time-step interval in seconds	ft/sec
D1	C	Perimeter of rectangular, round bottom conduit	ft
D1		Rate constant for decay	1/day
D2	C	Wetted perimeter of rectangular, round bottom conduit	ft
D2		Rate constant for reaeration	1/day
D2COLI		Total DWF coliform per subarea	MPN/sec
EPSIL	C	Allowable error for convergence in routing routine	
FAMILY		Number of people living in average dwelling unit within subarea KNUM	
FILTH		Name of subroutine	
FINDA		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
FIRST		Name of subroutine	
FON		Fraction of time-step pumped	
FRAC	C	Fraction of an inflow plug	
GEOM1	C	Conduit vertical dimension	ft
GEOM2	C	Conduit horizontal dimension	ft
GEOM3	C	Conduit dimension	ft
GINFIL		Groundwater infiltration	gpm
GNO	C	Supercritical flow indicator, flow not supercritical	
H		Head over weir	ft
HELP		Normalized area flow (= ALPHA)	
HVBOD	C	Hourly BOD variation factor	
HVCOLI	C	Hourly coliform variation factor in DWF	
HVDWF	C	Hourly sewage flow variation factor	
HVSS	C	Hourly SS variation factor	
I		Dimension and do loop counter	
I		Ratio of A/ΔA for linear interpolation counter (DPSI, PSI)	
ICHK		Newton-Raphson iteration check	
ICOST	C	Cost output control parameter	

Variable Name	C*	Description	Units
IFLOOD	C	Flood Indicator	
II		Do loop counters	
III		Do loop counters	
IK		Do loop counter for element number	
INCNT	C	Counting parameter for I/O input files	
INFIL		Name of subroutine	
INITAL	XF	Name of subroutine	
INPUT		External element number for flow and quality inputs to the sewer	
INUE	C	Internal upstream element numbers	
IOLD	C	Routing solution indicator	
IOUTCT	C	Counting parameter for I/O output files	
IP		Pollutant number	
IPOL	C	Pollution control parameter	
IPRINT	C	Print control parameter	
IR	C	Element number sequencing array	
ISTMOD	C	Storage mode parameter	
ISTOUT	C	Storage outlet type parameter	
ISTTYP	C	Storage reservoir type parameter	
ITER	C	Iteration number for routing	
J		Do loop counter	
JIN	C	Input file reference numbers	

Table 4-7 (continued)

Variable Name	C*	Description	Units
JJ		Do loop counter	
JN		External element numbers at which flow enters receiving water	
JOUT	C	Output file reference numbers	
JP		Number of first inlet plug in outflow	
JPLOT		Control parameter for plotting routed hydrographs and pollutographs	
JR	C	Element number sequencing array	
K		Interpolation warning flag	
KASE		Study area indicator	
KDAY		Number for the day of the week (Sunday = 1)	
KDEPTH	C	Parameter indicating form of input for D-A data	
KDT		Time-step number	
KFLAG		Interpolation warning flag	
KFULL	C	Parameter indicating surcharging	
KHOUR	C	Number for the hour of a day	hr
KJ		Do loop counter for time	
KLAND		Predominant land use within subarea	
KLASS	C	Parameter indicating form of input for Q-A data	
KMINS	C	Number for the minute of an hour	min
KNUM		Total number of subareas within a given study area in which sewage flow and quality are to be estimated	

Variable Name	C*	Description	Units
KP		Inlet plug number	
KPRINT		Control parameter for printing sewer cross-section data	
KSTOR	C	Storage unit number	
KSTORE	C	Storage element array	
KTNUM	C	Total number of subareas	
KTSTEP	C	Total Number of time-steps	
KUNIT	C	Parameter indicating units in which water usages are tabulated	
KVAL		Shields K as criterion for deposition and resuspension	
L		Size of data array	
L		GEOM3	
LABEL	C	Flag to label last increment of flow in plug flow	
LP	C	Number of last inlet plug in outflow	
LPREV	C	LP for previous time-step	
L1		Half width of the wetted surface in the element cross-sectional area	
M	C	Current internal element number	
METHOD		Parameter indicating whether or not water usage is metered	
MLTBE		Day on which melting period begins	
MLTEN		Day on which melting period ends	
MM	C	Total number of values of ANORM and QNORM	
MMM	C	Total number of values of ANORM and QNORM	

Table 4-7 (continued)

Variable Name	C	Description	Units
NSUBT		Subtotaling indicator for DWF output	
N	C	Current time-step number	
NAME	C	Name given to each user-supplied sewer cross-section	
NAREA1		Dummy variables used to calculate length of melting in INFIL	
NCNTRL		Control parameter for type of I/O interfacing mechanism	
ND		Do loop counter for converting unit	
NDD		Monthly degree/day values	degree-day
NDDAY		Subscript variable	
NDT	C	Total number of time-steps	
NDUM1		Total number of time-steps in runoff	
NDUM2		Size of time-step in RUNOFF, read off input file	sec
NDXDAY		Assigned daily degree/day values	degree-day
NDYUD		Day on which infiltration estimate is desired	
NE	C	Total number of sewer elements	
NEE		NE + 1	
NEP1		NE + 1	
NEWTON		Name of subroutine	
NFILTH		Control parameter for calling subroutine FILTH	
NGOTO		Element type number minus fifteen	
NIN	C	Internal element sequencing number	
NINFIL		Control parameter for calling subroutine INFIL	

Variable Name	C*	Description	Units
NINPUT		Total number of rainfall input locations to the sewer	
NITER		Maximum number of iterations to be made in flow routing	
NJ		Do loop counter for converting units	
NKLAS		NKLASS + 12	
NKLASS	C	Total number of user-supplied sewer cross-sections	
NN	C	Total number of values of DNORM	
NNEED		Dummy variable for sequencing elements	
NNH		Total number of values of DNORM	
NNPE		Total number of routed sewer hydrographs to be printed out	
NNYN		Total number of input hydrographs to be printed out	
NOE	C	External number of an element	
NORDER	C	External non-conduit element numbers at which runoff enters sewer	
NOS		Dummy variable	
NOUTS		Total number of hydrographs to the receiving water	
NPE	C	External element numbers at which routed outflow is printed	
NPF		Number of process flow	
NPOLL	C	Total number pollutants being routed	
NPOLS		NPOLL + 1	
NPRINT	C	Control parameter for printing sewer routing error messages	
NSCRAT	C	Data set reference numbers for temporary storage of data	

Table 4-7 (continued)

Variable Name	C*	Description	Units
NSCRAT	C	Scratch tape number	
NSTOR	C	Total number of storage units	
NT		Element type	
NTOT		Total number of degree days above 750	degree-day
NTRIN		Data set reference numbers for I/O file	
NTROUT		Data set reference numbers for I/O file	
NTU		Element type	
NTX		Scratch file	
NTYPE	C	Element type	
NUE	C	External upstream element numbers	
NX		Day numbers used in assigning daily degree/day values	
NX1		Day numbers used in assigning daily degree/day values	
NX2		Day numbers used in assigning daily degree/day values	
NY		Assigned daily degree/day values	
NYN	C	External element number at which inflow to sewer is printed	
NY1		Assigned daily degree/day values	degree-day
NY2		Assigned daily degree/day values	degree-day
OP		The preparation of total infiltration for each conduit	

Variable Name	C*	Description	Units
OPINF		Opportunity factor representing length of openings susceptible to infiltration for total areas	ft
OPNFIL		Opportunity factor representing susceptibility of each conduit to infiltration for individual areas	ft
OUT	C	Overflow hydrograph and pollutograph storage array	variable
OUTIN	C	Inflow hydrograph and pollutograph storage array	variable
OUT1	C	Printed outflows	cfs
OUT2	C	Printed pollutants	lb/min, MPN/min
O2DT2		Interpolated storage volume	cf
PCGG		Percent of dwelling units possessing garbage grinders within subarea KNUM	
PCT1		Fraction of sediment on bottom of sewer with diameter greater than or equal to CRITD	
PCT2		Fraction of sediment in suspension with diameter greater than or equal to CRITD	
PER		Wetted perimeter of modified cross-section area	ft
PLUTO	C	Pollutant ordinates from surface runoff	lb/min
POP		Total population in each subarea	
POPDEN		Population density per acre	
POPULA		Total population in all areas	thousands
PP		Same as OUT2	
PRICE		Cost of last thousand gallons of water per billing period	¢/1,000 gal.
PRINT		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
PS		Normalized flows	
PSI		Name of function	
PSI		Normalized flow, same as PS	
PSIMAX	C	Maximum Q/Q_f value	
PUMP	C	Constant pumping rate of pumps	cfs
P1	C	Conduit dimensional variable for computation purposes (FIRST)	
P2	C	Conduit dimensional variable for computation purposes (FIRST)	
P4	C	Conduit dimensional variable for computation purposes (FIRST)	
P5	C	Conduit dimensional variable for computation purposes (FIRST)	
P6	C	Conduit dimensional variable for computation purposes (FIRST)	
P7	C	Conduit dimensional variable for computation purposes (FIRST)	
Q	C	Sewer flows	cfs
QDWF	C	Sewage inflows	cfs
QFULL	C	Full flow capacity for conduits	cfs
QI	C	Sewer element inflow	cfs
QINF		Total infiltration	gpm
QINFIL	C	Groundwater infiltration inflows	cfs

Variable Name	C*	Description	Units
QINST	C	Water inflow rate to storage unit	cfs
QINSTL	C	Inflow rate previous time-step	cfs
QMAX	C	Maximum flow capacity for conduits	cfs
QNORM	C	Normalized flows	Q/Q_f
QO	C	Sewer element outflow	cfs
QOLD		Flow rate for previous time-step	cfs
QOUST	C	Outflow rate from storage unit	cfs
QOUSTL	C	Outflow rate previous time-step	cfs
QOUT		Outflow rate	cfs
QOUTO	C	Initial outflow rate	cfs
QO1	C	Undiverted flow in a flow divider or the flow going to the element number given in GEOM3	cfs
QO2	C	Diverted flow in a flow divider	cfs
QPF		Average daily process flow entering study system	cfs
QPUMP	C	Pumped outflow rate	cfs
QQ		Infiltration flow rate	cfs
QQDWF		Sum of DWF and infiltration flow	cfs
QQP		Ratio of total infiltration flow to DWF flow	
QUAL		Name of subroutine	
R	C	Same as P5, conduit dimensional variable for depth calculations	
RADH		Name of function	
RECEIV		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
RFACT	C	Factor to calculate full-flow hydraulic radius	
RH		Computation variable associated with conduit flow area	
RHYD		Hydraulic radius	ft
RINFIL		Average infiltration due to rain water infiltrating into pipes from the ground	gpm
RNOFF	C	Flow ordinates from surface runoff	cfs
ROUGH	C	Conduit roughness (Manning's n)	
ROUTE		Name of subroutine	
RR		Radius of the element (circular pipe)	
RSMAX		Peak infiltration caused by residual melting ice	gpm
S		Wetted perimeter (RADH)	ft
S		Saturation value for DO (QUAL)	mg/L
SABPF		BOD contributed from industrial process flow	mg/L
SAQPF		Total industrial process flow originating within subarea KNUM	cfs
SASPF		SS contributed by industrial process flows	mg/L
SBOD	C	BOD in storage unit	lb
SBODC		BOD concentration in storage unit	mg/L
SCF	C	Supercritical flow indicator	
SCOL		Coliform concentration in storage unit	lb
SCOLC		Coliform concentration in storage unit	MPN/ml
SCOUR	C	Sediment removed from conduits	lb
SEWAGE		Measured average sewage flow	cfs
SINFIL		Infiltration due to melting residual ice	gpm
SLOP		Name of subroutine	
SLOPE	C	Conduit invert slope	ft/ft ft/100 ft
SLUPE		Slope of line $-C_1\alpha - C_2$ on Figure 4-18	
SMMBOD		Summation of BOD in system	lb/sec/DT
SMMDWF		Summation of DWF in system	cfs
SMMQQ		Summation of infiltration flow rate in system	cfs
SMMSS		Summation of SS in system	lb/sec/DT
SMTDWF		Sum total of DWF and infiltration	cfs
SPG		Specific gravity of sediment	
SSCONC		Total and subtotal SS concentration of DWF	mg/L
SSCOUT		SS concentration in outflow	mg/L
SSIN	C	SS inflow rate	lb/DT
SSOUT	C	SS outflow rate	lb/DT
SSS	C	SS in storage unit	lb
SSSC		SS concentration in storage unit	mg/L
STOR	C	Water in storage	cf
STORF	C	Storage at end of storm	cf
STORL	C	Stored water previous time-step	cf
STORMX	C	Maximum storage during storm	cf
STORO	C	Initial storage	cf
SUMBOD		Sum of BOD from all process flow	lb/sec
SUMINF		Sum of DINFIL and RINFIL	gpm
SUMQPF		Sum of the process flows from all locations	cfs

Table 4-7 (continued)

Variable Name	C*	Description	Units
SUMSS		Sum of SS from all process flow	lb/sec
SUM1		Sum for sewer flows	cfs
SUM2		Sum for concentration of pollution, SS	lb/sec
SUM3		The amount of solids held in suspension due to velocity of flow	lb/sec
SURGE1	C	Surcharged flow volume, last time-step	cf
SURGE2	C	Surcharged flow volume, this time-step	cf
SLSPP		Average daily SS of process flow	
TBODOT		Total BOD discharged from outfall	lb
TCA		Total contributing commercial area	acres
TCOLI		Total coliform in DWF per day	MPN/day
TDTR		Total contributing area except industrial and park and open space area	acres
TDWFA		Total computed residential and commercial area which contributed to DWF	acres
TERM		Term in routing equation	
THETA		The angle which is drawn from center of cross-section area to the wetted surface	radian
TIME	C	Time from start of simulation	sec
TIME2M		Time since start of inflow	min
TINA		Total contributing industrial area	acres
TITLE	C	Title associated with I/O	
TOTA		Total study area from which ABOD and ASUSO were taken	acres
TOTAL		Sum of all incoming sewer flow	cfs
TOTAL1		Sum of all pollutant flow rates from sewer element immediately upstream	lb/sec
TOTAL2		Pollutant flow rate of incoming DWF	variable
TOTAL3		Pollutant flow rate of incoming runoff	lb/sec
TOTAL4		Pollutant flow rate of all flow and scouring effect	lb/sec
TOTBOD		Total of BOD	lb/day
TOTPOP		Total population	
TOTSS		Total SS	lb/day
TPOA		Total park and open space area	acres
TRAA		Total contributing average income below $15,000 but above $7,000 residential area	acres
TRANS		Name of subroutine	
TRGGA		Total area from TRHA, TRAA, TRLA that contributes additional waste from garbage grinders	acres
TRHA		Total contributing high income above $15,000 residential area	acres
TRLA		Total contributing low income below $7,000 residential area	acres
TSSOUT		Total SS discharged from outfall	lb
TSTCST		Name of subroutine	
TSTORG		Name of subroutine	
TSTRDT		Name of subroutine	
TZERO		Time storm started	sec
ULEN		Average distance between joints in study area sewers	ft
ULIMIT		Upper limit of bed load of solids	lb

Table 4-7 (continued)

Variable Name	C*	Description	Units
VALUE		Market value of average dwelling unit within subarea KNUM	$1000's
VEL		Name of a function	
VOLIN	C	Water inflow per time-step	cf
VOLOUT	C	Water outflow per time-step	cf
VOL1		Previous volume of wastewater within each element	cf
VOL2		Current volume of wastewater within each element	cf
WATER		Winter water use for KNUM (units of KNUM)	variable
WD		Weight on spatial derivative in routing flows	
WDWF	C	Sewage pollutant concentrations	lb/sec
WTDWFA		Weight strength of DWF contributing area (not including industrial and park and open area)	acres
WDWF1		Daily adjusted sewage BOD concentration	lb/sec
WDWF2		Daily adjusted sewage SS concentration	lb/sec
WDWF3		Daily adjusted sewage coliform concentration	MPN/sec
WEIRHT		Weir height	ft
WEIRL		Weir length	ft
WELL1	C	Wet well volume for lift stations	cf
WELL2	C	Wet well volume for lift stations	cf
WSLOPE		Slope of water surface	ft/ft
WT		Weight on time derivative in routing flows	
X		Data array member	
XE		Input to interpolation routine	
XINCOM		Income of average family living	$1000's
XL		Width of rectangular pipe	ft
XMLTBE		Floating point number MLTBE	
XMLTEN		Floating point number MLTEN	
XNDYUD		Floating point number NDYUD	
XXARG		Dummy variable used to calculate SINFIL	
Y		Data array member	
YE		Output value from interpolation routine	
YES	C	Supercritical flow indicator, flow is supercritical	

EXAMPLES

Three examples of the use of the Transport Block or its subroutines are given:

Example 1 - The complete Transport Block but with Internal
Storage and Infiltration not called.

Example 2 - Subroutine INFIL.

Example 3 - Subroutine FILTH.

Actual I/O information are used in part to illustrate these examples.

Example 1 - Transport Block

The sewer system shown in Figure 4-37 will be used to illustrate I/O sections of the Transport program. The system is a hypothetical one made up of 17 conduits linked by manholes or other types of non-conduits. All 12 program-provided conduit shapes have been utilized in the system for purposes of illustration. The system outfall is at element 114.

Description of Sample Data. Table 4-8 shows a listing of actual data presented to the program for execution. The data have been broken up into four sections; a verbal description of the implications of each section follows.

Section A

Section A lists the following example I/O specifications:

- No new conduit shapes are to be added.
- It is desired to print all flow-area relationships.
- Title card.
- There are 32 total elements in the system.

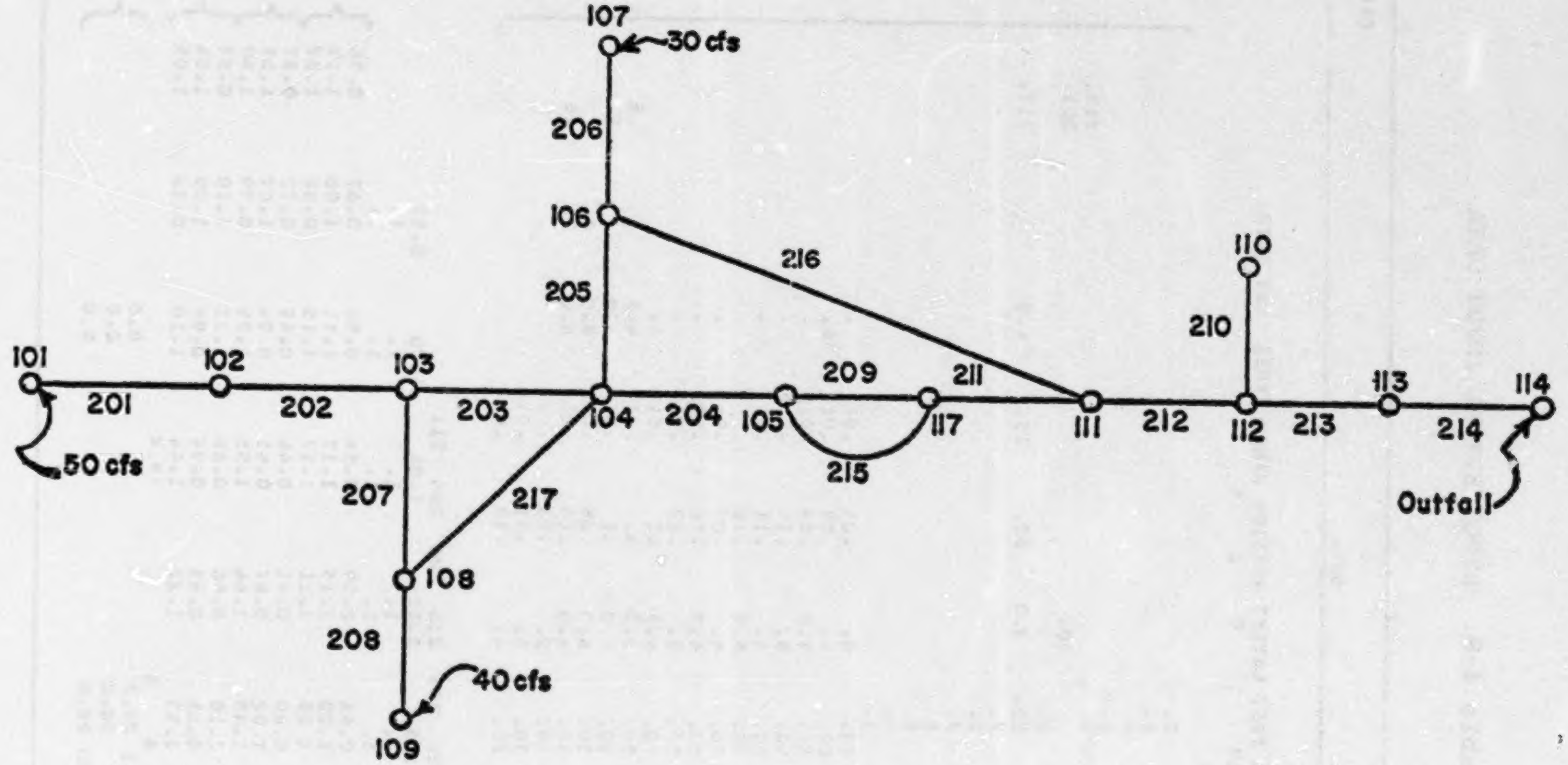

107
30 cfs
206
106
216
205
110
210
101
201
102
202
103
203
104
204
105
209
117
211
111
212
112
213
113
214
114
50 cfs
215
207
217
Outfall
108
208
40 cfs
109

Figure 4-37. EXAMPLE SYSTEM FOR I/O DISCUSSION

Table 4-8. HYPOTHETICAL INPUT DATA

```
                                                                                         CARD GROUP
                                          DATA                                              NO.

        0    1                                                                              1
    1 HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES  MAY 1970                     11
A      32   50    3    3   10     1   0    2     4                                         12
       240.     .0001     1.                                                               13
        1    0    1    1                                                                 14
      101   0   0   0  16     8.
      102 201   0   0  16     8.
      103 202 207   0  16     8.
      104 203 205 217  16     8.
      105 204   0   0  21     8.                                            215.
      106 206   0   0  18           20.                                     205.
      107   0   0   0  16     8.
      108 208   0   0  20     22.   2.0     62.     13.     4.5             217.
      109   0   0   0  16     8.
      110   0   0   0  16     8.
      111 211 216   0  16     8.
      112 212 210   0  16     8.
      113 213   0   0  16     8.
      114 214   0   0  16     8.
      117 215 209   0  16     8.
B     201 101   0   0   1   50.     5.      .06     .013     .                             15
      202 102   0   0   2   50.     4.      .08     .013    6.
      203 103   0   0   3   50.     7.0     .09     .013     .
      204 104   0   0   4   50.     8.      .1      .013     .
      205 106   0   0   5   50.     4.      .11     .013     .
      206 107   0   0   6   50.     5.5     .10
      207 108   0   0   7   50.     4.      .05     .013     .
      208 109   0   0   8   50.     4.5     .10     .013     .
      209 105   0   0   9   50.     6.      .12     .013     .
      210 110   0   0  10   50.     4.5     .1      .013    4.
      211 117   0   0  11   50.     5.0     3.      .013    4.5             .5
      212 111   0   0  12   50.     5.0     .1      .013    6.0             8.
      213 112   0   0   2   50.     6.0     .05     .013    8.0     2.
      214 113   0   0  11   50.     6.0     .08     .013    8.0     2.      .6
      215 105   0   0   1   55.     2.      .06     .013
      216 106   0   0   1   70.     6.      .01     .013
      217 108   0   0   9   60.     4.      .12     .013
      114                                                                                  27
C     101  109  107                                                                        28
      208  207  217  203  206  205  216  204  209  111                                     29
      0.96      1.08      1.05      0.90       1.04     1.00      0.97                       33
        1.        1.        1.        1.        1.        1.        1.                     34
        1.        1.        1.        1.        1.        1.        1.                     35
        0.74      0.67      0.63      0.59      0.54      0.56      0.67       0.96
        1.42      1.19      1.20      1.15      1.17      1.11      1.08       1.15        36
        1.21      1.23      1.25      1.21      1.17      1.15      0.38       1.07
        0.85      0.71      0.60      0.41      0.46      0.49      0.72       0.87
D       0.77      1.57      1.02      0.87      0.91      0.94      1.07       1.07        37
        1.14      0.99      1.45      1.66      1.55      1.29      0.79       1.60
        1.05      1.05      1.10      0.50      0.66      1.33      1.10       0.88
        1.03      0.91      0.66      0.63      0.94      0.94      1.05       1.05        38
        1.16      0.94      1.33      1.22      1.44      1.10      0.88       1.05
        3    2    0    6    6    6                14.2                                     40
      11011              0.5 25.0                           0.0
      21111  1500.           50.0                           0.0                            44
      31041             0.61 25.0                           0.0
```

- Simulation will occur over 50 time-steps.
- There are three inflows to the system. All three of these inputs are to be printed out.
- Ten outflows are to be printed out.
- Outflow for one element is to be written on tape.
- No tracing messages are to be generated.
- Two pollutants (BOD and SS) are to be routed.
- Four iterations will be used in the routing routine.
- Time-step interval is 240 sec.
- The iteration convergence criterion is 0.0001.
- One day of dry weather occurred prior to the storm.
- Transfer between Model blocks is by either tape or disk.
- Infiltration into the sewer is not estimated.
- Combined sewer will be modeled by estimating sanitary flows.
- The output will be printed in tabular form.

Section B

This section physically describes the sewer system in terms of its geometry and dimensions. Refer to Table 4-4 for data requirements of each type of conduit shape. The three non-conduits that are not manholes are elements 105 (type 21 flow-divider), 106 (type 18 flow-divider), and 108 (type 20 flow-divider).

Section C

These three input records specify that the outflow hydrograph and pollutographs for element 114 will be provided on tape for subsequent use by other programs of the Storm Water Management Model, that input hydrographs and pollutographs will be printed out for elements 101, 109, and 107, and that the ten elements for which outflow hydrographs and pollutographs to be printed out are elements 208, 207, 217, 203, 206, 205, 216, 204,209, and 111.

It should be pointed out that input hydrographs and pollutographs for the three elements mentioned were provided via tape by the Runoff program and they consisted of a constant inflow rate over the time of simulation, i.e.,

Manhole Number	Input Hydrograph, cfs	Input Pollutograph, lb/min
101	50	1
109	40	2
107	30	1

Section D

These data satisfy the requirements of subroutine FILTH as applied to this particular system. Only a small amount of wastewater flow enters the system at elements 101, 111, and 104. The description of data for a similar system is covered elsewhere in this manual.

Notice that data for infiltration are omitted (Card Group 14 set INFIL = 0). For purposes of simplicity in this execution, infiltration was assumed non-existent in this hypothetical sewer system.

Description of Sample Output. Many options are available to the user for output retrieval from the Transport program. In this example, only the most illustrative ones have been selected and these are shown in Tables 4-9 and 4-10.

Table 4-9. FLOW-AREA PARAMETERS FOR TRANS EXAMPLE

```
                                           UNIVERSITY OF FLORIDA TRANSPORT MODEL
LIST OF PARAMETERS DESCRIBING DIFFERENT SEWER ELEMENTS.

CONDUITS

NTYPE  DESCRIPTION       ALFMAX  PSIMAX  AFACT   RFACT  KDEPTH  KLASS  INDEX  ANORM   GNORM     CNORM
  1    CIRCULAR SHAPED  0.9600  1.0800  0.7854  0.2500    2       2       1   0.0     0.0       0.0
                                                                           2   0.020   0.00526   0.05273
                                                                           3   0.040   0.01414   0.08574
                                                                           4   0.060   0.02553   0.24194
                                                                           5   0.080   0.03862   0.41581
                                                                           6   0.100   0.05315   0.15280
                                                                           7   0.120   0.06877   0.16653
                                                                           8   0.140   0.08551   0.18558
                                                                           9   0.160   0.10326   0.20799
                                                                          10   0.180   0.12195   0.23186
                                                                          11   0.200   0.14144   0.25386
                                                                          12   0.220   0.16162   0.27118
                                                                          13   0.240   0.18251   0.28900
                                                                          14   0.260   0.20410   0.30658
                                                                          15   0.280   0.22636   0.32349
                                                                          16   0.300   0.24918   0.34017
                                                                          17   0.320   0.27246   0.35666
                                                                          18   0.340   0.29614   0.37298
                                                                          19   0.360   0.32027   0.38915
                                                                          20   0.380   0.34485   0.40521
                                                                          21   0.400   0.36989   0.42117
                                                                          22   0.420   0.39531   0.43704
                                                                          23   0.440   0.42105   0.45284
                                                                          24   0.460   0.44704   0.46858
                                                                          25   0.480   0.47329   0.48430
                                                                          26   0.500   0.49980   0.50000
                                                                          27   0.520   0.52658   0.51572
                                                                          28   0.540   0.55354   0.53146
                                                                          29   0.560   0.58064   0.54723
                                                                          30   0.580   0.60777   0.56305
                                                                          31   0.600   0.63459   0.57892
                                                                          32   0.620   0.66232   0.59487
                                                                          33   0.640   0.68995   0.61093
                                                                          34   0.660   0.71770   0.62710
                                                                          35   0.680   0.74538   0.64342
                                                                          36   0.700   0.77275   0.65991
                                                                          37   0.720   0.79979   0.67659
                                                                          38   0.740   0.82658   0.69350
                                                                          39   0.760   0.85320   0.71068
                                                                          40   0.780   0.87954   0.72816
                                                                          41   0.800   0.90546   0.74602
                                                                          42   0.820   0.93095   0.76424
                                                                          43   0.840   0.95577   0.78297
                                                                          44   0.860   0.97976   0.80235
                                                                          45   0.880   1.00291   0.82240
                                                                          46   0.900   1.02443   0.84353
                                                                          47   0.920   1.04465   0.86563
                                                                          48   0.940   1.06135   0.88970
                                                                          49   0.960   1.08208   0.91444
                                                                          50   0.980   1.07662   0.94749
                                                                          51   1.000   1.00000   1.00000
 15    USER SUPPLIED    0.9600  1.0000  0.0     0.0       2       2       1   0.0     0.0       0.0

NON-CONDUITS

  NTYPE  KDEPTH  KLASS  DESCRIPTION


   16      3       3    MANHOLE

   17      3       3    LIFT STATION

   18      3       3    FLOW DIVIDER

   19      3       3    STORAGE UNIT

   20      3       3    FLOW DIVIDER

   21      3       3    FLOW DIVIDER

   22      3       3    BACKWATER UNIT
```

Table 4-10. SEQUENCE NUMBERING FOR TRANS EXAMPLE

```
HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES  MAY 1970

EXTERNAL  TYPE  DESCRIPTION         UPSTREAM ELEMENTS  INTERNAL          ELEMENT COMPUTATION SEQUENCE
ELEMENT                                 1    2    3    ELEMENT       EXTERNAL  INTERNAL  INTERNAL UPSTREAM
NUMBER                                                 NUMBER        NUMBER    NUMBER    ELEMENT NUMBERS
  101      16   MANHOLE                 0    0    0        1           101         1       33    33    33
  102      16   MANHOLE               201    0    0        2           107         7       33    33    33
  103      16   MANHOLE               202  207    0        3           109         9       33    33    33
  104      16   MANHOLE               203  205  217        4           110        10       33    33    33
  105      21   FLOW DIVIDER          204    0    0        5           201        16        1    33    33
  106      18   FLOW DIVIDER          206    0    0        6           102         2       16    33    33
  107      16   MANHOLE                 0    0    0        7           202        17        2    33    33
  108      20   FLOW DIVIDER          208    0    0        8           206        21        7    33    33
  109      16   MANHOLE                 0    0    0        9           106         6       21    33    33
  110      16   MANHOLE                 0    0    0       10           205        20        6    33    33
  111      16   MANHOLE               211  216    0       11           208        23        9    33    33
  112      16   MANHOLE               212  210    0       12           108         8       23    33    33
  113      16   MANHOLE               213    0    0       13           207        22        8    33    33
  114      16   MANHOLE               214    0    0       14           103         3       17    22    33
  117      16   MANHOLE               215  209    0       15           203        18        3    33    33
  201       1   CIRCULAR SHAPED       101    0    0       16           210        25       10    33    33
  202       2   RECTANGULAR           102    0    0       17           216        31        6    33    33
  203       3   EGG-SHAPED            103    0    0       18           217        32        8    33    33
  204       4   HORSE SHOE            104    0    0       19           104         4       18    20    32
  205       5   GOTHIC SHAPED         106    0    0       20           204        19        4    33    33
  206       6   CATENARY SHAPED       107    0    0       21           105         5       19    33    33
  207       7   SEMI ELLIPTICAL       108    0    0       22           209        24        5    33    33
  208       8   BASKET HANDLE         109    0    0       23           215        30        5    33    33
  209       9   SEMI CIRCULAR         105    0    0       24           117        15       30    24    33
  210      10   MODIFIED B. H.        110    0    0       25           211        26       15    33    33
  211      11   RECT. - TRIANG.       117    0    0       26           111        11       26    31    33
  212      12   RECT. - ROUND         111    0    0       27           212        27       11    33    33
  213       2   RECTANGULAR           112    0    0       28           112        12       27    25    33
  214      11   RECT. - TRIANG.       113    0    0       29           213        28       12    33    33
  215       1   CIRCULAR SHAPED       105    0    0       30           113        13       28    33    33
  216       1   CIRCULAR SHAPED       106    0    0       31           214        29       13    33    33
  217       9   SEMI CIRCULAR         108    0    0       32           114        14       29    33    33
```

Table 4-9 shows the first piece of output relating to flow-area parameters for the different types of conduit shapes. In total, 12 of these tables are printed. Only the table for type 1 (circular conduit) is shown here. At the end of these tables, parameters for non-conduit types are also printed. This section of the output is constant for all runs made. In other words, it will not change from sewer system to sewer system, unless the user wishes to insert additional conduit shapes. In that case, the added flow-area relationships will also appear in this section.

Table 4-10 shows the next section of output. It consists of the external and internal numbering system used by the program in sequencing the sewer elements.

The most important part of the output is shown in Table 4-11, which describes the sewer system in terms of element types, dimensions, slopes, areas, and flow capacities. This information is strictly based upon the data provided by the user. Careful inspection of this output will detect any errors made during data preparation.

The output from subroutine FILTH follows and is shown in Table 4-12.

Table 4-13 contains the section of output describing the initial conditions prior to the storm to be simulated. Notice that flow initial conditions are simply set equal to wastewater flow (infiltration was zero in this case).

Table 4-11. ELEMENT DATA FOR TRANS EXAMPLE

```
HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES  MAY 1970
       NUMBER OF ELEMENTS=   32
       NUMBER OF TIME INT=   50
            TIME INTERVAL=  240.0 SECONDS.

ELEMENT PARAMETERS
 EXT. TYPE  DESCRIPTION          SLOPE   DISTANCE  MANNING     GEOM1   GEOM2   GEOM3   NUMBER    AFULL     QFULL     QMAX     SUPER-CRITICAL
 ELE.                           (FT/FT)    (FT)    ROUGHNESS    (FT)    (FT)    (FT)     OF     (SQ.FT)    (CFS)     (CFS)    FLOW WHEN LESS
 NUM.                                                                                 BARRELS                                 THAN 95  FULL
 101   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 102   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 103   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 104   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 105   21   FLOW DIVIDER       0.0         8.00   0.0          2.778   0.0   215.000    1.0     0.0        0.0       0.0
 106   18   FLOW DIVIDER       0.0         0.0    0.0         20.000   0.0   205.000    1.0     0.0        0.0       0.0
 107   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 108   20   FLOW DIVIDER      62.00000    22.00  13.0000       2.000   4.500217.000     1.0     0.0        0.0       0.0
 109   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 110   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 111   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 112   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 113   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 114   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 117   16   MANHOLE            0.0         8.00   0.0          0.0     0.0     0.0      1.0     0.0        0.0       0.0
 201    1   CIRCULAR SHAPED    0.00060    50.00   0.0130       5.000   0.0     0.0      1.0    19.635     63.967    69.084       NO
 202    2   RECTANGULAR        0.00080    50.00   0.0130       4.000   6.000   0.0      1.0    24.000     87.859   107.155       NO
 203    3   EGG-SHAPED         0.00090    50.00   0.0130       7.000   0.0     0.0      1.0    25.014    105.150   111.985       NO
 204    4   HORSE SHOE         0.00100    50.00   0.0130       8.000   0.0     0.0      1.0    53.075    308.452   332.203       NO
 205    5   GOTHIC SHAPED      0.00110    50.00   0.0130       4.000   0.0     0.0      1.0    10.486     37.368    39.796       NO
 206    6   CATENARY SHAPED    0.00100    50.00   0.0130       5.500   0.0     0.0      1.0    21.259     90.573    95.102       NO
 207    7   SEMI ELLIPTICAL    0.00050    50.00   0.0130       4.000   0.0     0.0      1.0    12.560     31.499    32.917       NO
 208    8   BASKET HANDLE      0.00100    50.00   0.0130       4.500   0.0     0.0      1.0    15.921     61.816    65.573       NO
 209    9   SEMI CIRCULAR      0.00120    50.00   0.0130       6.000   0.0     0.0      1.0    45.709    265.313   282.922       NO
 210   10   MODIFIED B. H.     0.00100    50.00   0.0130       4.500   4.000  18.000    1.0    24.283    108.963   108.196       NO
 211   11   RECT. - TRIANG.    0.03000    50.00   0.0130       5.000   4.500   0.500    1.0    21.375    473.920   559.577       YES
 212   12   RECT. - ROUND      0.00100    50.00   0.0130       5.000   6.000   8.000    1.0    32.353    150.953   181.793       NO
 213    2   RECTANGULAR        0.00050    50.00   0.0130       6.000   8.000   0.0      2.0    48.000    176.207   212.155       NO
 214   11   RECT. - TRIANG.    0.00080    50.00   0.0130       6.000   8.000   0.600    2.0    45.600    210.220   259.302       NO
 215    1   CIRCULAR SHAPED    0.00060    55.00   0.0130       2.000   0.0     0.0      1.0     3.142      5.556     6.001       NO
 216    1   CIRCULAR SHAPED    0.00010    70.00   0.0130       6.000   0.0     0.0      1.0    28.274     42.465    45.862       NO
 217    9   SEMI CIRCULAR      0.00120    60.00   0.0130       4.000   0.0     0.0      1.0    20.315     89.988    95.960       NO


 EPSILON=0.000100      NO. OF ITERATIONS IN ROUTING ROUTINE =

HYDROGRAPHS AND POLLUTOGRAPHS PROVIDED TO SUBSEQUENT PROGRAMS FOR THE FOLLOWING ELEMENTS
 114
```

Table 4-12. DRY WEATHER FLOW FOR TRANS EXAMPLE

```
              QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA


                       A1BOD =   1300.00  LBS/DAY/CFS
                        A1SS =   1420.00  LBS/DAY/CFS


                                               AVERAGES

         MANHOLE                      CFS         LBS/SEC  LBS/SEC       ACRES
KNUM      INPUT         KLAND         DWF         DWBOD    DWSS          AREA

  1        101            1           0.50         1.44     1.58        25.00
  2        111            1           0.08         0.22     0.24        50.00
  3        104            1           0.61         1.76     1.92        25.00



                  DAILY AND HOURLY CORRECTION FACTORS
                           FOR SEWAGE DATA

             DAY                  DVDWF       DVBOD       DVSS

          1                       0.960       1.000       1.000
          2                       1.080       1.000       1.000
          3                       1.050       1.000       1.000
          4                       0.900       1.000       1.000
          5                       1.040       1.000       1.000
          6                       1.000       1.000       1.000
          7                       0.970       1.000       1.000

             HOUR

          1                       0.740       0.850       1.050
          2                       0.670       0.710       1.050
          3                       0.630       0.600       1.100
          4                       0.590       0.410       0.500
          5                       0.540       0.460       0.660
          6                       0.560       0.490       1.330
          7                       0.670       0.720       1.100
          8                       0.960       0.870       0.880
          9                       1.420       0.770       1.030
         10                       1.190       1.570       0.910
         11                       1.200       1.020       0.660
         12                       1.150       0.870       0.630
         13                       1.170       0.910       0.940
         14                       1.110       0.940       0.940
         15                       1.080       1.070       1.050
         16                       1.150       1.070       1.050
         17                       1.210       1.140       1.160
         18                       1.230       0.990       0.940
         19                       1.250       1.450       1.330
         20                       1.210       1.660       1.220
         21                       1.170       1.550       1.440
         22                       1.150       1.290       1.100
         23                       0.880       0.990       0.880
         24                       1.070       1.600       1.050
```

Table 4-13. INITIAL CONDITIONS FOR TRANS EXAMPLE

```
                    INITIAL BED OF SOLIDS (LBS) IN SEWER DUE TO
                       1.C DAYS OF DRY WEATHER PRIOR TO STCRM

                    ELEMENT                      SOLIDS IN
                    NUMBER                         BOTTOM
                                                    (LBS)


                       201                       13.03258
                       202                       28.48965
                       2C6                        C.0
                       205                        0.0
                       208                        0.0
                       207                        0.0
                       203                        2.22038
                       210                        0.0
                       216                        0.0
                       217                        0.0
                       2C4                        3.80130
                       2C9                        C.0
                       215                        4.56354
                       211                        0.0
                       212                        5.54245
                       213                      138.90474
                       214                       29.25818


ELEMENT FLOWS, AREAS, AND CCNCENTRATICNS ARE INITIALIZED TO DRY WEATHER FLOW AND INFILTRATION VALUES.
ELE.NO.  TYPE  FLOW     AREA   CONC1   CONC2   CONC3   CONC4   CONC5   CONC6
  101     16   0.500   0.0     0.0120  0.C131
  107     16   C.C     0.0     0.0     0.0
  109     16   C.C     0.C     C.C     0.C
  110     16   C.C     0.0     0.0     0.C
  201      1   0.500   0.506   0.0120  0.C131
  102     16   0.500   0.0     0.C120  0.0131
  202      2   0.5C0   0.677   C.C120  0.C131
  206      6   C.C     0.C     0.0     0.C
  106     18   0.C     0.C     0.0     0.C
  205      5   0.C     0.0     0.C     0.0
  208      8   C.C     0.0     C.C     0.C
  108     20   C.C     0.0     C.0     0.C
  207      7   0.C     0.C     C.0     0.C
  103     16   0.5C0   0.0     0.C120  0.0131
  203      3   C.5C0   0.587   C.C120  0.C131
  210     10   C.C     0.C     0.0     0.C
  216      1   0.0     0.C     0.0     0.C
  217      9   0.C     0.0     0.0     0.C
  104     16   1.110   0.0     0.C120  0.C131
  204      4   1.110   0.818   C.0120  0.C131
  105     21   1.110   0.0     0.0120  0.0131
  209      9   0.0     0.0     0.C     0.0
  215      1   1.110   0.804   0.C120  0.C131
  117     16   1.110   0.0     C.C120  0.C131
  211     11   1.110   0.241   0.C120  0.C131
  111     16   1.187   0.0     0.C120  0.C131
  212     12   1.187   0.475   C.C120  0.C131
  112     16   1.187   0.0     0.0120  0.C131
  213      2   1.187   0.968   0.0120  0.0131
  113     16   1.187   0.0     0.0120  0.0131
  214     11   1.187   0.641   0.0120  0.C131
  114     16   1.187   0.0     0.0120  0.C131
```

After the storm has passed through the system, the total pounds of solids left deposited within the sewer elements are printed out. This is shown in Table 4-14.

The final section of the output relates to input and output hydrographs and pollutographs which were specified by the user to be printed out. Table 4-15 shows the three described inflows and Table 4-16 shows the ten desired outflows.

Example 2 - Subroutine INFIL

The Pine Valley area of Baltimore, Maryland, is used in the following example to demonstrate the application of INFIL. In this case, the groundwater table was taken as being below the sewer. Historical climatalogical and flow data are available for estimating infiltration on April 15.

1. DINFIL

   Historical flow data from the previous year indicate that minimum average flow was approximately 50 gpm. Since only 30 gpm can be attributed to sewage, DINFIL is taken as 20 gpm.

2. SINFIL

   From a heating and air conditioning handbook (Ref. 1), degree-days are found to be well above 750 prior to April. Since frost and other residual moisture will contribute if melting occurs during April 15, degree-days NDD were input to subroutine INFIL. Based upon these data, INFIL computed that thawing begins on March 10 (i.e.,238 days from beginning of degree day data or MLTBE = 238 and ends on May 1 (i.e.,

Table 4-14. FINAL CONDITIONS FOR TRANS EXAMPLE

```
           BED OF SOLIDS IN SEWER AT END OF STORM

    ELEMENT                        SOLIDS IN
    NUMBER                          BOTTOM
                                     (LBS)


      201                          0.01315
      202                          0.01148
      206                          0.00762
      205                          0.00537
      208                          0.01294
      207                          0.04432
      203                          0.01204
      210                          0.0
      216                          1.86356
      217                          0.00791
      204                          0.01414
      209                          0.00759
      215                          0.02499
      211                          0.0
      212                          0.01659
      213                          0.05283
      214                          0.03813
```

Table 4-15. INFLOWS FOR TRANS EXAMPLE

```
  HYPOTHETICAL SEWER SYSTEM FOR ILLUSTRATION PURPOSES
 TOTAL SIMULATION TIME=12000.0 SECONDS. TIME STEP= 240.0 SECONDS.

 INFLOW POLLUTOGRAPHS AND HYDROGRAPHS AT THE FOLLOWING  EXTERNAL ELEMENT NUMBERS
  101  109  107

                                         SELECTED INLET HYDROGRAPHS - CFS
 EXTERNAL
 ELEMENT    TIME STEP
 NUMBER        1         2         3         4         5         6         7         8         9        10

  101        50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
             50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
             50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
             50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
             50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
  109        40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000
             40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000
             40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000
             40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000
             40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000    40.000
  107        30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000
             30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000
             30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000
             30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000
             30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000    30.000

                                         SELECTED INLET POLLUTOGRAPHS - LBS/DT
 EXTERNAL
 ELEMENT    TIME STEP
 NUMBER        1         2         3         4         5         6         7         8         9        10

                                         *** BOD ***

  101         4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000

                                         ** SUSPENDED SOLIDS **

  101         4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
              4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000     4.000
```

Table 4-15. (continued)

```
                                   *** BOD ***

109       8.000     8.000     8.CC0     8.0C0     8.000     8.000     8.000     8.000     8.CC0     8.CC0
          8.CCC     8.C00     8.CC0     8.CC0     8.000     8.000     8.CC0     8.000     8.CC0     8.CC0
          8.CC0     8.CC0     8.0C0     8.C00     8.000     8.000     8.0C0     8.C00     8.CC0     8.C00
          8.C00     8.CC0     8.0C0     8.000     8.000     8.000     8.000     8.000     8.CC0     8.C00
          8.C00     8.000     8.0C0     8.CC0     8.000     8.000     8.0C0     8.000     8.0C0     8.CC0

                                ** SUSPENDED SCLIDS **

109       8.CCC     8.000     8.CC0     8.CC0     8.000     8.CC0     8.CC0     8.000     8.CC0     8.CC0
          8.CCC     8.000     8.CC0     8.CC0     8.000     8.000     8.0C0     8.CC0     8.CC0     8.C00
          8.CC0     8.CC0     8.CC0     8.C00     8.000     8.000     8.0C0     8.CC0     8.CCC     8.C00
          8.CCC     8.C00     8.CC0     8.000     8.000     8.C00     8.000     8.C00     8.CC0     8.C00
          8.0CC     8.000     8.0C0     8.CC0     8.000     8.000     8.CC0     8.000     8.CC0     8.CC0

                                   *** BOD ***

107       4.0C0     4.000     4.0C0     4.000     4.000     4.000     4.000     4.000     4.C00     4.CC0
          4.CCC     4.000     4.0C0     4.CC0     4.000     4.000     4.0C0     4.C00     4.CC0     4.CC0
          4.CC0     4.CC0     4.0C0     4.C00     4.000     4.000     4.000     4.C00     4.CCC     4.C00
          4.0C0     4.000     4.0C0     4.000     4.000     4.000     4.000     4.C00     4.C00     4.000
          4.CC0     4.C00     4.000     4.CC0     4.000     4.000     4.0C0     4.C00     4.000     4.CC0

                                ** SUSPENDED SCLIDS **

107       4.C00     4.C00     4.CC0     4.000     4.000     4.0C0     4.0C0     4.000     4.CC0     4.CC0
          4.CCC     4.C00     4.CC0     4.CC0     4.000     4.000     4.0C0     4.000     4.CC0     4.CC0
          4.0C0     4.CC0     4.CC0     4.CC0     4.000     4.000     4.0C0     4.000     4.CCC     4.CC0
          4.CCC     4.000     4.0C0     4.000     4.000     4.000     4.000     4.000     4.CC0     4.000
          4.0C0     4.000     4.0C0.    4.CC0     4.000     4.000     4.0C0     4.000     4.000     4.C00
```

Table 4-16. OUTFLOWS FOR TRANS EXAMPLE

EXTERNAL ELEMENT NUMBER	SELECTED OUTFLOW HYDROGRAPHS - CFS									
	TIME STEP 1	2	3	4	5	6	7	8	9	10
208	36.343	42.936	38.476	40.414	39.771	40.018	39.979	40.016	39.983	40.011
	39.987	40.008	39.989	40.006	39.991	40.004	39.993	40.002	39.994	40.001
	39.995	40.000	39.996	40.000	39.996	39.999	39.996	39.998	39.998	39.998
	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998
	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998
207	9.312	19.969	13.636	15.964	15.195	15.513	15.479	15.525	15.489	15.525
	15.494	15.522	15.498	15.519	15.501	15.517	15.503	15.515	15.505	15.514
	15.506	15.513	15.507	15.512	15.507	15.511	15.508	15.509	15.509	15.509
	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509
	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509
217	22.226	25.954	23.539	24.813	24.256	24.607	24.414	24.521	24.469	24.496
	24.484	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
203	46.289	78.932	60.753	65.903	65.344	65.685	65.733	65.796	65.762	65.802
	65.772	65.811	65.777	65.846	65.836	65.846	65.830	65.855	65.840	65.847
	65.841	65.861	65.845	65.840	65.843	65.844	65.842	65.842	65.970	65.998
	65.978	65.995	65.993	65.995	65.993	65.995	65.994	65.995	65.994	65.995
	65.994	65.995	65.994	66.185	66.242	66.210	66.217	66.211	66.227	66.219
206	27.217	32.189	28.811	30.429	29.759	30.022	29.971	30.004	29.996	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
205	17.972	21.590	19.192	20.222	19.853	20.036	19.979	20.016	19.984	20.012
	19.988	20.009	19.991	20.007	19.993	20.005	19.995	20.004	19.996	20.003
	19.997	20.002	19.998	20.002	19.998	20.001	19.999	20.001	19.999	20.001
	19.999	20.001	19.999	20.000	20.000	20.000	20.000	20.000	20.000	20.000
	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
216	4.364	13.382	8.640	10.286	10.312	10.005	10.041	9.999	9.990	9.993
	9.993	9.995	10.012	9.997	9.992	9.997	10.010	9.998	10.001	10.000
	10.000	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999
	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999
	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999

Table 4-16. (continued)

204	80.697	129.826	103.011	111.077	109.842	110.619	110.517	110.624	110.601	110.607
	110.623	110.613	110.630	110.714	110.755	110.719	110.746	110.731	110.753	110.727
	110.751	110.743	110.754	110.725	110.749	110.731	110.747	110.731	111.035	111.070
	111.055	111.067	111.069	111.067	111.069	111.067	111.069	111.068	111.069	111.068
	111.068	111.069	111.068	111.516	111.613	111.559	111.576	111.561	111.580	111.575
209	71.852	129.761	99.464	108.218	107.121	107.804	107.746	107.849	107.838	107.833
	107.859	107.841	107.865	107.946	107.993	107.953	107.982	107.966	107.989	107.963
	107.986	107.980	107.989	107.961	107.984	107.968	107.982	107.968	108.233	108.310
	108.268	108.295	108.285	108.294	108.286	108.293	108.287	108.293	108.288	108.292
	108.287	108.293	108.288	108.720	108.844	108.777	108.800	108.781	108.802	108.796
111	77.122	146.626	110.925	121.119	120.423	120.482	120.728	120.571	120.728	120.583
	120.724	120.616	120.730	120.723	120.853	120.748	120.845	120.774	120.834	120.833
	120.833	120.833	120.833	120.833	120.833	120.833	120.833	120.833	121.051	121.107
	121.099	121.162	121.162	121.162	121.162	121.162	121.162	121.162	121.162	121.162
	121.162	121.162	121.162	121.582	121.748	121.650	121.650	121.650	121.650	121.713

Table 4-16. (continued)

EXTERNAL ELEMENT NUMBER	SELECTED OUTFLOW POLLUTOGRAPHS - LBS/DT									
	TIME STEP 1	2	3	4	5	6	7	8	9	10
				*** BOD ***						
208	7.201	8.765	7.460	8.315	7.751	8.174	7.856	8.117	7.903	8.079
	7.935	8.053	7.956	8.036	7.970	8.024	7.980	8.016	7.986	8.011
	7.990	8.007	7.993	8.005	7.995	8.003	7.997	8.002	7.998	8.001
	7.999	8.001	7.999	8.000	7.999	8.000	7.999	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				** SUSPENDED SOLIDS **						
208	7.190	8.763	7.460	8.315	7.753	8.173	7.858	8.116	7.904	8.078
	7.936	8.053	7.956	8.036	7.971	8.024	7.980	8.016	7.986	8.011
	7.991	8.008	7.994	8.005	7.996	8.004	7.997	8.002	7.998	8.002
	7.999	8.001	7.999	8.001	7.999	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				*** BOD ***						
207	1.815	4.121	2.624	3.272	2.995	3.124	3.091	3.100	3.108	3.092
	3.113	3.091	3.112	3.092	3.110	3.094	3.108	3.096	3.107	3.098
	3.105	3.099	3.104	3.100	3.103	3.101	3.103	3.101	3.103	3.101
	3.102	3.101	3.102	3.101	3.102	3.102	3.102	3.102	3.102	3.102
	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
				** SUSPENDED SOLIDS **						
207	1.772	4.107	2.635	3.256	3.007	3.123	3.094	3.099	3.109	3.092
	3.113	3.091	3.112	3.093	3.110	3.095	3.108	3.097	3.107	3.098
	3.105	3.099	3.104	3.100	3.103	3.101	3.103	3.101	3.103	3.101
	3.103	3.101	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
				*** BOD ***						
217	4.348	5.411	4.415	5.213	4.661	5.054	4.795	4.958	4.863	4.914
	4.893	4.895	4.904	4.888	4.908	4.887	4.907	4.888	4.906	4.890
	4.904	4.892	4.902	4.893	4.901	4.895	4.900	4.896	4.859	4.896
	4.859	4.897	4.859	4.897	4.898	4.897	4.898	4.897	4.858	4.897
	4.898	4.897	4.858	4.898	4.898	4.898	4.898	4.898	4.898	4.898
				** SUSPENDED SOLIDS **						
217	4.334	5.406	4.417	5.212	4.664	5.053	4.797	4.957	4.864	4.914
	4.893	4.895	4.905	4.889	4.908	4.888	4.908	4.889	4.906	4.891
	4.904	4.892	4.903	4.894	4.901	4.895	4.900	4.896	4.900	4.896
	4.859	4.897	4.859	4.897	4.899	4.897	4.898	4.898	4.858	4.898
	4.898	4.898	4.858	4.898	4.898	4.898	4.898	4.898	4.898	4.898

Table 4-16. (continued)

				*** BOD ***						
203	6.760	8.796	7.569	7.580	7.932	7.669	7.883	7.765	7.826	7.806
	7.801	7.823	7.793	8.072	8.178	8.124	8.144	8.146	8.132	8.152
	8.130	8.152	8.132	8.149	8.134	8.147	8.137	8.145	8.300	8.394
	8.335	8.370	8.352	8.360	8.359	8.356	8.361	8.355	8.361	8.355
	8.360	8.356	8.360	8.252	8.190	8.227	8.205	8.217	8.213	8.212
				** SUSPENDED SOLIDS **						
203	40.586	27.333	0.0	15.196	5.261	11.562	7.860	9.835	9.023	9.089
	9.481	8.831	9.605	8.529	9.163	8.520	9.133	8.571	9.073	8.634
	9.011	8.692	8.960	8.737	8.919	8.772	8.890	8.796	8.617	8.408
	8.543	8.458	8.508	8.482	8.493	8.492	8.487	8.495	8.485	8.495
	8.486	8.455	8.487	8.670	8.762	8.707	8.736	8.723	8.727	8.729
				*** BOD ***						
206	3.594	4.383	3.723	4.175	3.863	4.093	3.924	4.060	3.952	4.038
	3.969	4.025	3.979	4.016	3.987	4.011	3.991	4.007	3.994	4.004
	3.996	4.003	3.997	4.002	3.998	4.001	3.999	4.001	3.999	4.000
	3.999	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
				** SUSPENDED SOLIDS **						
206	3.588	4.381	3.723	4.175	3.864	4.092	3.924	4.059	3.952	4.038
	3.969	4.025	3.980	4.016	3.987	4.011	3.991	4.007	3.994	4.005
	3.996	4.003	3.998	4.002	3.998	4.001	3.999	4.001	3.999	4.001
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
				*** BOD ***						
205	2.348	2.989	2.414	2.823	2.547	2.743	2.616	2.699	2.647	2.677
	2.662	2.667	2.669	2.663	2.671	2.661	2.672	2.662	2.671	2.662
	2.670	2.663	2.669	2.664	2.669	2.665	2.668	2.665	2.668	2.666
	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.666
	2.667	2.666	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667
				** SUSPENDED SOLIDS **						
205	2.340	2.986	2.416	2.822	2.549	2.743	2.617	2.698	2.647	2.677
	2.662	2.667	2.669	2.663	2.671	2.662	2.672	2.662	2.671	2.663
	2.670	2.664	2.669	2.664	2.669	2.665	2.668	2.665	2.668	2.666
	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.667	2.667	2.667
	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667

Table 4-16. (continued)

				*** BOD ***						
216	C.55C	1.857	1.1C1	1.397	1.375	1.324	1.350	1.322	1.341	1.325
	1.338	1.327	1.339	1.329	1.335	1.331	1.336	1.331	1.335	1.332
	1.334	1.332	1.334	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.233
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
				** SUSPENDEC SCLIOS **						
216	C.317	1.310	0.975	1.215	1.245	1.139	1.2C0	1.223	1.262	1.285
	1.306	1.314	1.324	1.320	1.328	1.330	1.333	1.329	1.331	1.331
	1.332	1.332	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.233	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.233
	1.333	1.233	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
				*** BOD ***						
204	14.C66	18.242	15.273	16.333	16.131	16.203	16.278	16.171	16.3C2	16.166
	16.303	16.172	16.295	16.786	17.106	16.878	17.043	16.922	17.C13	16.942
	17.CCO	16.952	16.994	16.956	16.989	16.960	16.986	16.962	17.380	17.498
	17.43C	17.467	17.450	17.455	17.457	17.452	17.458	17.452	17.457	17.453
	17.456	17.454	17.455	17.196	17.096	17.158	17.119	17.142	17.129	17.137
				** SUSPENDED SCLIUS **						
204	5C.115	43.082	7.314	26.394	15.248	21.246	18.702	19.149	19.934	18.510
	2C.195	18.487	20.081	18.018	18.967	18.142	18.821	18.288	18.688	18.405
	18.588	18.487	18.525	18.535	18.488	18.561	18.471	18.571	17.841	17.711
	17.753	17.765	17.722	17.780	17.716	17.780	17.720	17.775	17.726	17.768
	17.732	17.763	17.738	18.190	18.325	18.245	18.290	18.266	18.278	18.274
				*** BOD ***						
209	12.424	18.838	14.129	16.462	15.264	16.189	15.522	16.069	15.623	16.CC0
	15.678	15.959	15.712	16.479	16.556	16.572	16.502	16.602	16.490	16.604
	16.494	16.597	16.5C3	16.587	16.512	16.579	16.519	16.573	16.885	17.1C4
	16.962	17.054	16.993	17.035	17.005	17.028	17.009	17.026	17.C10	17.C25
	17.011	17.024	17.012	16.793	16.656	16.738	16.689	16.716	16.703	16.709
				** SUSPENDED SOLIDS **						
209	44.238	47.C97	5.136	26.098	15.312	19.914	19.087	17.906	2C.029	17.635
	19.920	17.944	19.532	17.750	18.268	17.936	18.088	18.090	17.968	18.178
	17.908	18.213	17.895	18.210	17.907	18.190	17.933	18.162	17.398	17.275
	17.301	17.326	17.276	17.334	17.279	17.326	17.289	17.316	17.298	17.308
	17.305	17.302	17.3C9	17.694	17.897	17.772	17.847	17.802	17.830	17.812

Table 4-16. (continued)

	••• BOD •••									
111	14.232 17.673 18.530 19.008 19.032	20.812 17.663 18.400 18.933 18.929	16.043 17.704 18.533 19.035 19.028	18.134 18.238 18.396 18.919 18.679	17.349 18.619 18.535 19.042 18.632	17.859 18.353 18.395 18.917 18.620	17.544 18.553 18.536 19.040 18.665	17.758 18.392 18.395 18.921 18.600	17.624 18.532 18.927 19.036 18.676	17.698 18.400 18.982 18.925 18.597
	•• SUSPENDED SOLIDS ••									
111	48.955 22.431 20.131 19.441 19.395	52.512 19.731 20.115 19.173 19.196	6.356 21.943 20.118 19.404 19.390	28.096 19.582 20.112 19.191 19.631	17.851 20.527 20.131 19.397 20.023	21.216 19.811 20.093 19.192 19.728	21.767 20.326 20.155 19.398 19.959	19.305 19.981 20.068 19.191 19.768	22.655 20.193 19.564 19.398 19.934	19.250 20.078 19.105 19.192 19.786

MLTEN = 289) with April 15 (i.e., NDYUD = 274) occurring during this period. From historical flow data, the maximum incremental flow due to spring thaw appears to be nearly 65 gpm. It follows that SINFIL is:

$$\text{SINFIL} = \text{RSMAX*SIN}(360^\circ/2*(\text{NDYUD} - \text{MLTBE})/(\text{MLTEN} - \text{MLTBE})) \tag{8}$$

$$= 65*\text{SIN}(127^\circ)$$

$$= 52 \text{ gpm.}$$

3. RINFIL

Total precipitation on April 15 and the previous 9 days was 1.81 inches for this example. RINFIL could then be estimated from a regression equation based upon previous flow data.

For Pine Valley, sewer flow data not affected by spring thaw were correlated with antecedent rainfall in the following manner. These sanitary sewage flows were first adjusted to remove accounted for sewage and dry weather infiltration for each day.

$$\text{RINFIL(I)} = \text{SWFLOW(I)} - \text{SMMDWF} - \text{DINFIL} \tag{9}$$

where

SWFLOW(I) = Average sewer flow on day I.

Linear regression was then performed on the following data yielding Eq. 10.

Date	RINFIL, gpm	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
		in./day									
June											
1	28.87	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00	0.00	0.00
2	24.64	0.00	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00	0.00
3	19.68	0.11	0.00	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00
etc.				etc.							
	dependent	independent variables									

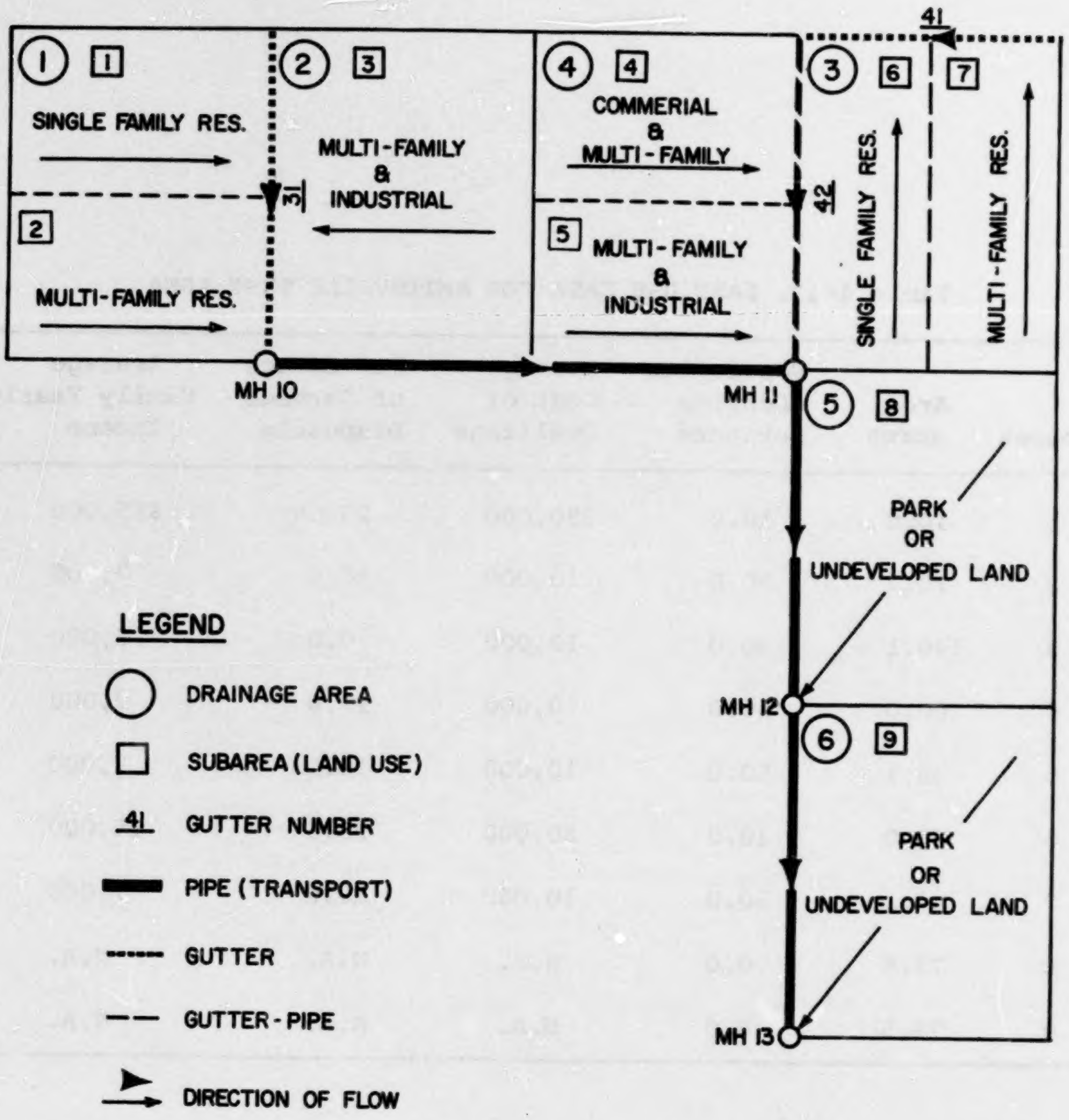
$$\mathrm{RINFIL} = 2.40 + 11.3X_1 + 11.6X_2 + 5.5X_3 + 6.4X_4 + 4.8X_5 + 3.6X_6 + 1.0X_7 + 1.5X_8 + 1.4X_9 + 1.8X_{10} \qquad (10)$$

For April 15, RINFIL was then calculated to be 10.2 gpm. Therefore, QINFIL = 20.0 + 52.0 + 10.2 = 82.2 gpm.

Example 3 - Subroutine FILTH

A hypothetical test area, Smithville, total population 15,000, is used as an example to demonstrate the application of subroutine FILTH. The test area is made up of six subcatchment basins and nine land use areas as shown in Figure 4-38. It was assumed that flow records and water metering records were unavailable. The industrial and commercial flows, however, were known for subareas 3, 4, and 5.

A Case 2 procedure was followed using the default values for AlBOD, AlSS and AlColi. The areas, population density, cost of the dwellings, percentage of houses having garbage disposal units, and the average income of the families within each subarea are given in Table 4-17. The start of the storm simulation is on a Monday at 1:30 p.m.



41
1
1
2
3
4
4
3
6
7
SINGLE FAMILY RES.
MULTI-FAMILY & INDUSTRIAL
COMMERIAL & MULTI-FAMILY
31
42
SINGLE FAMILY RES.
MULTI-FAMILY RES.
2
MULTI-FAMILY RES.
5
MULTI-FAMILY & INDUSTRIAL
MH 10
MH 11
5
8
PARK OR UNDEVELOPED LAND
LEGEND
DRAINAGE AREA
SUBAREA (LAND USE)
41 GUTTER NUMBER
PIPE (TRANSPORT)
GUTTER
GUTTER-PIPE
DIRECTION OF FLOW
MH 12
6
9
PARK OR UNDEVELOPED LAND
MH 13

Figure 4-38. SCHEMATIC OF SMITHVILLE TEST AREA

Table 4-17. LAND USE DATA FOR SMITHVILLE TEST AREA

Subarea	Area, acres	Population Density per acre	Average Cost of Dwellings	Percentage of Garbage Disposals	Average Family Yearly Income
1	10.0	10.0	$50,000	25.0%	$15,000
2	10.7	50.0	10,000	10.0	7,000
3	140.1	30.0	10,000	0.0	5,000
4	60.0	50.0	10,000	10.0	7,000
5	38.1	50.0	10,000	10.0	7,000
6	50.0	10.0	50,000	25.0	15,000
7	44.1	50.0	10,000	10.0	7,000
8	73.5	0.0	N.A.	N.A.	N.A.
9	73.5	0.0	N.A.	N.A.	N.A.

The data deck for FILTH is shown in Table 4-18. The first three data cards are the average daily variations for DWF, BOD, and SS. No daily variation for coliforms is modeled. The following 12 cards, in groups of threes, define the changes from daily averages to hourly flow rates and concentrations for flow, BOD, SS, and coliforms, respectively. The starting value of each group represents the 1 a.m. condition. These factors are reproduced in the computer output as a check (shown in Table 4-20.) The remaining card groups represent the information about each subarea. Card group 39 is a control card. It should be noted that for subareas 3, 4, and 5, dummy subareas (31, 41, and 51) were introduced giving a total of 12 subareas to account for the multiple land uses.

The output from FILTH (Table 4-19) is in two parts. The first group of values expresses the default concentrations of BOD, SS, and coliforms along with the yearly average daily flow. The second block gives the calculated values for each subarea taking into account the time and the day of the week the simulation occurred. Subtotals were requested for each inlet manhole.

Table 4-18. DATA DECK FOR SMITHVILLE TEST AREA

```
                                          DATA                                CARD GROUP
                                                                                  NO.
      0.96      1.08      1.05      0.90      1.04      1.00      0.97
      1.00      1.00      1.00      1.00      1.00      1.00      1.00               32-34
      1.00      1.00      1.00      1.00      1.00      1.00      1.00
      0.74      0.67      0.63      0.59      0.54      0.56      0.67      0.96
      1.42      1.19      1.20      1.15      1.17      1.11      1.09      1.15     35
      1.21      1.23      1.25      1.21      1.17      1.15      0.88      1.07
      0.85      0.71      0.60      0.41      0.46      0.49      0.72      0.87
      0.77      1.57      1.02      0.87      0.91      0.94      1.07      1.07     36
      1.14      0.99      1.45      1.16      1.55      1.29      0.99      1.60
      1.05      1.05      1.10      0.50      0.66      1.33      1.10      0.88
      1.03      0.91      0.66      0.63      0.94      0.94      1.05      1.05     37
      1.16      0.94      1.33      1.22      1.44      1.10      0.88      1.05
      1.10      0.64      0.45      0.87      0.54      0.48      1.29      1.18
      1.37      1.49      1.30      1.12      0.89      0.58      0.45      0.67     38
      0.96      1.18      0.84      1.01      2.82      1.77      0.84      0.71
  12     2    3    2   13   30              15.000                                 39
  1 101                  10.0 10.0           50.0 25.0                15.0
  2 102                  10.7 50.0           10.0 10.0                 7.0
  3 102                 140.1 30.0           10.0  0.0                 5.0
 31 104                                                5.00 200. 200.      1
  4 112                  60.0 50.0           10.0 10.0                 7.0
 41 113                                                0.80 190. 220.                43
  5 112                  38.1 50.0           10.0 10.0                 7.0
 51 114                                                3.00 200. 200.
  6 111                  50.0 10.0           50.0 25.0                15.0
  7 112                  44.1 50.0           10.0 10.0                 7.0 1
  8 125                  73.5                                              1
  9 135                  73.5                                              1
```

Table 4-19. DATA OUTPUT FOR SMITHVILLE TEST AREA

```
                 DAILY AND HOURLY CORRECTION FACTORS
                          FOR SEWAGE DATA

   DAY              DVDWF      DVBOD      DVSS       DVCOLI

    1               0.960      1.000      1.000
    2               1.080      1.000      1.000
    3               1.050      1.000      1.000
    4               0.900      1.000      1.000
    5               1.040      1.000      1.000
    6               1.000      1.000      1.000
    7               0.970      1.000      1.000

   HOUR

    1               0.740      0.850      1.050      1.100
    2               0.670      0.710      1.050      0.640
    3               0.630      0.600      1.100      0.450
    4               0.590      0.410      0.500      0.870
    5               0.540      0.460      0.660      0.540
    6               0.560      0.490      1.330      0.480
    7               0.670      0.720      1.100      1.290
    8               0.960      0.870      0.880      1.180
    9               1.420      0.770      1.030      1.370
   10               1.190      1.570      0.910      1.490
   11               1.700      1.020      0.660      1.300
   12               1.150      0.870      0.630      1.120
   13               1.170      0.910      0.940      0.890
   14               1.110      0.940      0.940      0.580
   15               1.080      1.070      1.050      0.450
   16               1.150      1.070      1.050      0.670
   17               1.210      1.140      1.160      0.960
   18               1.230      0.990      0.940      1.180
   19               1.250      1.450      1.330      0.840
   20               1.210      1.160      1.220      1.010
   21               1.170      1.550      1.440      2.820
   22               1.150      1.290      1.100      1.770
   23               0.880      0.990      0.880      0.840
   24               1.070      1.600      1.050      0.710
```

Table 4-20. DATA OUTPUT FOR SMITHVILLE TEST AREA

```
                         QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA


                   A1BOD =   1300.00LBSPERDAY/CFS
                    A1SS =   1420.00 LBSPERDAY/CFS
                  A1COLI =   2.00E 11 MPN/DAY PER CAPITA
                    ADWF =      2.32 CFS


KNUM INPUT       DWF  +  INFIL  =  QQDWF KLAND     DWBOD      DWSS         TOTPOP   BODCONC   SSCONC    COLIFORMS
                 CFS     CFS       CFS             LBS/MIN    LBS/MIN      PERSONS  MG/L      MG/L      MPN/100ML

   1   10        0.02    0.01      0.03    1       0.02       0.02
   2   10        0.05    0.02      0.07    2       0.04       0.05
   3   10        0.38    0.17      0.55    2       0.27       0.30
  31   10        5.00    2.27      7.27    4       3.74       3.74
        SUBTOTALS

                 5.44    2.47      7.91           20.39 LBS  20.55 LBS    4838.     138.      139.      6.14E 07

   4   11        0.27    0.12      0.39    2       0.25       0.27
  41   11        0.80    0.36      1.16    3       0.65       0.71
   5   11        0.17    0.08      0.25    2       0.16       0.17
  51   11        3.00    1.36      4.36    4       2.25       2.25
   6   11        0.09    0.04      0.13    1       0.09       0.10
   7   11        0.20    0.09      0.29    2       0.18       0.20
        SUBTOTALS

                 9.97    4.52     14.49           38.28 LBS  39.05 LBS   12448.     141.      144.      7.16E 06

   8   12        0.0     0.0       0.0     5       0.0        0.0
        SUBTOTALS

                 9.97    4.52     14.49           38.28 LBS  39.05 LBS   12448.     141.      144.      7.02E 06

   9   13        0.0     0.0       0.0     5       0.0        0.0
        SUBTOTALS

                 9.97    4.52     14.49           38.28 LBS  39.05 LBS   12448.     141.      144.      7.02E 06


        TOTALS

                 9.97    4.52     14.49           38.28 LBS  39.05 LBS   12448.     141.      144.      7.02E 06
```

SECTION 5

STORAGE BLOCK

Page

BLOCK DESCRIPTION 225

- Broad Description of Storage 227
- Broad Description of Treatment 227
- Broad Description of Cost Estimation 229

SUBROUTINE DESCRIPTIONS 229

- Subroutine STORAG 229
- Subroutine TRTDAT 230
- Subroutine STRDAT 230
- Subroutine TREAT 235
- Subroutine STRAGE 235
- Subroutine TRCOST 240
- Support Subroutines 240

INSTRUCTIONS FOR DATA PREPARATION 244

- Programming Limitations 247
- Storage Model 249
  - Step 1 - Flow and Quality Input 249
  - Step 2 - Storage-Treatment String 249
  - Step 3 - Output 249
  - Step 4 - Storage Unit 249
  - Step 5 - Unit Cost 250
  - Step 6 - Treatment and Treatment Cost Data 250
  - Step 7 - Starting Time 250
- Treatment Model 250
  - Step 2 - Storage-Treatment String 250
  - Step 6 - Treatment and Treatment Cost Data 251
- Cost Model 251

EXAMPLES 272

- Example 1 - With Storage, Treatment and Cost 272
  - Description of Sample Data 272
  - Description of Sample Output 274
- Example 2 - Treatment and Cost, Only 283
  - Description of Sample Data 283
  - Description of Sample Output 283

BLANK PAGE

SECTION 5

STORAGE BLOCK

BLOCK DESCRIPTION

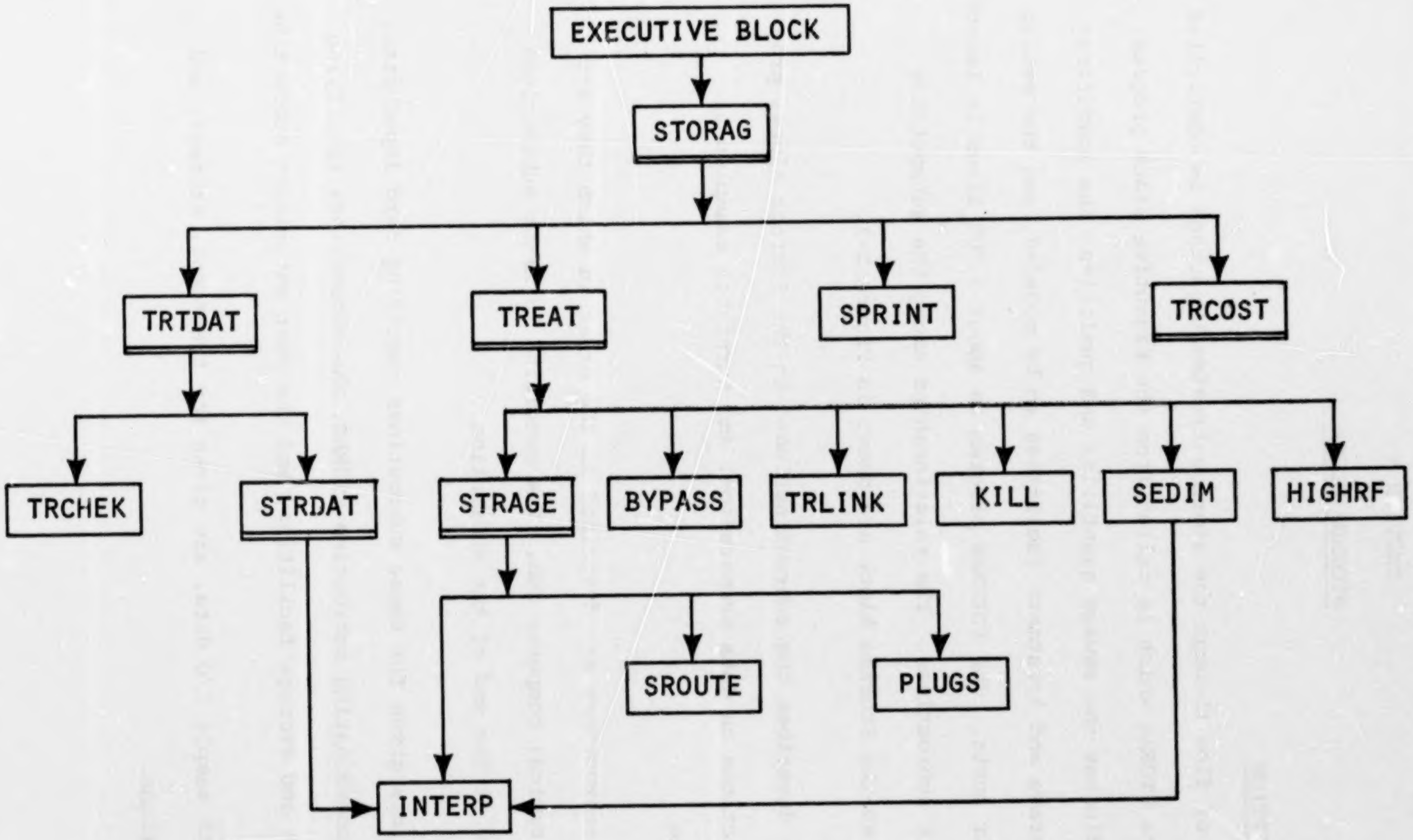
The routing of flow through the storage-treatment package is controlled by subroutine STORAG which is called from the Executive Block program. STORAG coordinates the sewage quantities and qualities, the specifications of storage and treatment facilities to be modeled, and the estimation of their costs. The FORTRAN program is about 3,700 lines in length, comprising 16 subroutines. The relationships among the subroutines which comprise the Storage Block are shown in Figure 5-1.

This section describes the subroutines used in the Storage Block, provides instructions on data preparation, and furnishes examples of program usage.

The 6 major subroutines are described in the order in which they are called in a typical computer run. The remaining 10 minor subroutines are described at the end of the subsection.

Instructions are given for those subroutines requiring card input data, namely, the coordinating subroutine STORAG, the subroutines specifying the treatment and storage facilities, and the cost estimation subroutine.

Examples, with sample I/O data, are given for treatment, storage, and cost computations.


EXECUTIVE BLOCK
STORAG
TRTDAT
TREAT
SPRINT
TRCOST
TRCHEK
STRDAT
STRAGE
BYPASS
TRLINK
KILL
SEDIM
HIGHRF
SROUTE
PLUGS
INTERP

NOTE: BOXES WITH DOUBLE UNDERLINE REPRESENT MAJOR SUBROUTINES.

Figure 5-1. STORAGE BLOCK

Broad Description of Storage

With the Storage Model, holding or routing functions may be modeled in irregular or geometric shaped storage units, and with alternative inlet and outlet controls such as by weir, orifice, or pumping. The characteristics of the storage unit are first specified in subroutine STRDAT, and the flow of water and pollutants are then simulated each time-step by subroutine STRAGE. With gravity outflows, routing is performed by subroutine SROUTE. Two optional types of through-flow are suitable, i.e., plug flow (subroutine PLUGS) and complete mixing.

This external version of storage, as opposed to the internal version incorporated within the Transport Model, cannot be used without including specifications for sedimentation within the storage basin. The resuspension of solids settled in storage is not modeled.

Broad Description of Treatment

The quality of the storm or combined sewer overflow may be improved by passing the sewage through a treatment package made up by the user. The treatment package is composed by selecting treatment processes from the options indicated in Figure 5-2, thus forming a computational string. The characteristics of the treatment package are first specified in subroutine TRTDAT, and the sewage flows and treatment are then simulated each time-step by subroutine TREAT, aided by a number of minor subroutines (see Figure 5-1) as needed.

Treatment packages not including storage may be modeled by specifying the appropriate bypass, Option 01.

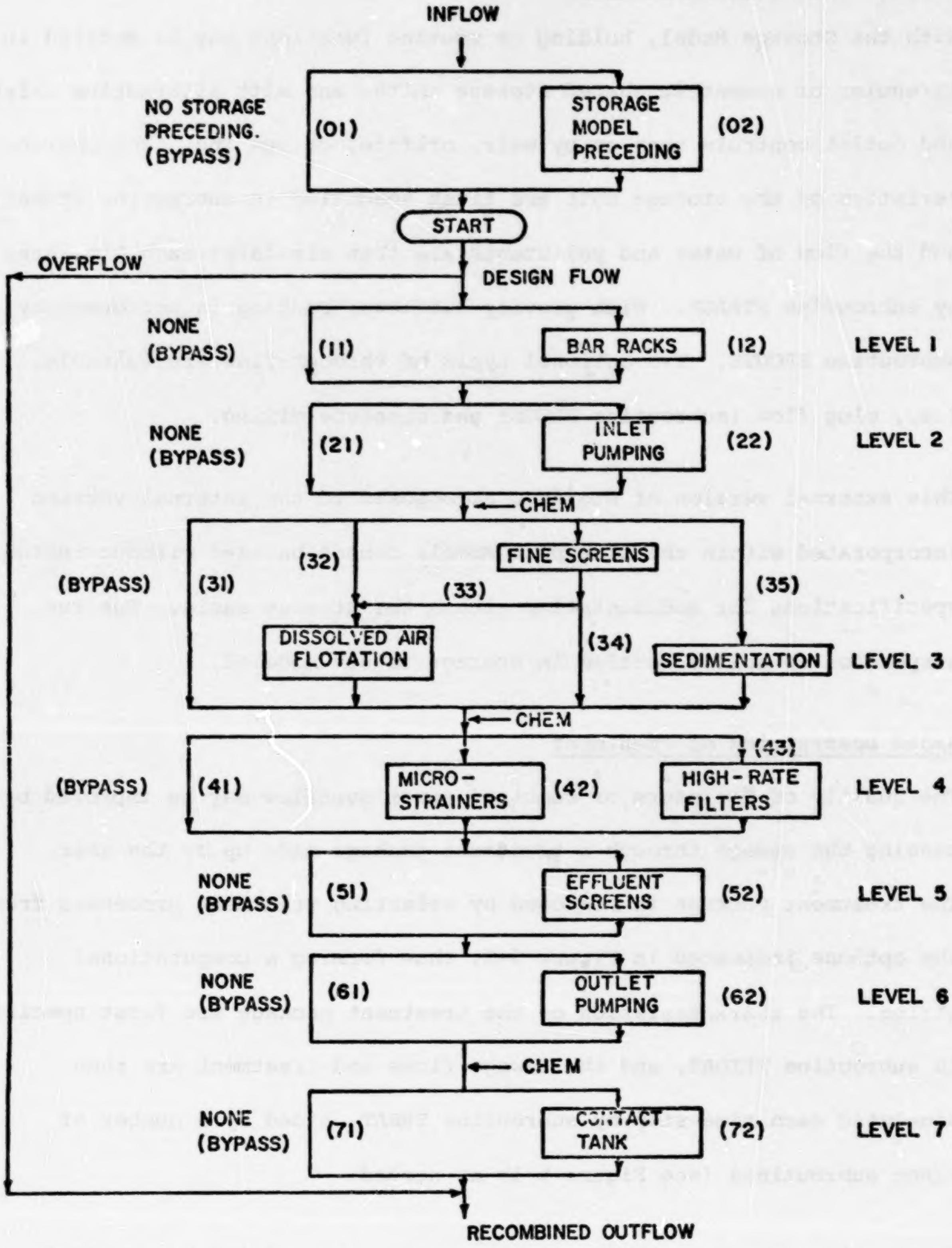

INFLOW
NO STORAGE PRECEDING. (BYPASS)
(01)
STORAGE MODEL PRECEDING
(02)
START
OVERFLOW
DESIGN FLOW
NONE (BYPASS)
(11)
BAR RACKS
(12)
LEVEL 1
NONE (BYPASS)
(21)
INLET PUMPING
(22)
LEVEL 2
CHEM
FINE SCREENS
(BYPASS)
(31)
(32)
(33)
(35)
DISSOLVED AIR FLOTATION
(34)
SEDIMENTATION
LEVEL 3
CHEM
(43)
(BYPASS)
(41)
MICRO-STRAINERS
(42)
HIGH-RATE FILTERS
LEVEL 4
NONE (BYPASS)
(51)
EFFLUENT SCREENS
(52)
LEVEL 5
NONE (BYPASS)
(61)
OUTLET PUMPING
(62)
LEVEL 6
CHEM
NONE (BYPASS)
(71)
CONTACT TANK
(72)
LEVEL 7
RECOMBINED OUTFLOW

Figure 5-2. AVAILABLE TREATMENT OPTIONS

Broad Description of Cost Estimation

Subroutine TRCOST handles the estimation of all storage and treatment costs after the storm simulation has been completed. Capital costs for the supply, installation, and required land for each process included in the string are computed, from which annual costs are derived. Storm event costs, such as those for chemicals consumed and operation and maintenance, are also computed.

SUBROUTINE DESCRIPTIONS

Subroutine STORAG Ⓒ

Subroutine STORAG is the coordinating program for all water and pollutant movements through the storage and treatment facilities modeled. The Storage Block handles the following pollutants: BOD, suspended solids, and total coliforms.

All interfacing with the Executive Block, and thus I/O statements requiring off line (tape/disk) units are located in STORAG. The inflow hydrographs and pollutographs received in this way are fed on a time-step basis to the appropriate subroutines for processing. Any number of runs with different storage/treatment options and the same inflow data may be executed at the one time, but only the first has output written on the output file. This output is written in the same format as the Transport Model output, in order to be equally acceptable as input to the Receiving Water Model. STORAG also controls the input of storage/treatment specifications (subroutine TRTDAT), the printing of final quantity and quality outputs (subroutine SPRINT), and the estimation of storage/treatment costs (subroutine TRCOST).

A flow chart of subroutine STORAG is shown in Figure 5-3.

Subroutine TRTDAT ①

This subroutine reads in all the data needed to specify the various treatment processes selected, and computes from them any further parameters needed.

Parameters specifying the treatment options required are read in first (see Figure 5-2 for options available at various levels of treatment). Parameters which control printout of intermediate and summarized treatment information are then read in.

The design flow capacity for the entire treatment installation is then determined by specification or by the inflow hydrograph. If chlorination is specified somewhere within the treatment package, the chlorinator is sized in this subroutine.

Last, any design criteria needed for selected treatment processes are read in on a process-by-process basis in accordance with the specified computational string.

An outline flow chart of subroutine TRTDAT is shown in Figure 5-4.

Subroutine STRDAT ⑤

If a storage unit is to be included in the Block, this subroutine reads in all the data needed to specify its various characteristics, and computes from them any further parameters needed. A diagrammatic sketch of a storage unit is shown in Figure 5-5.

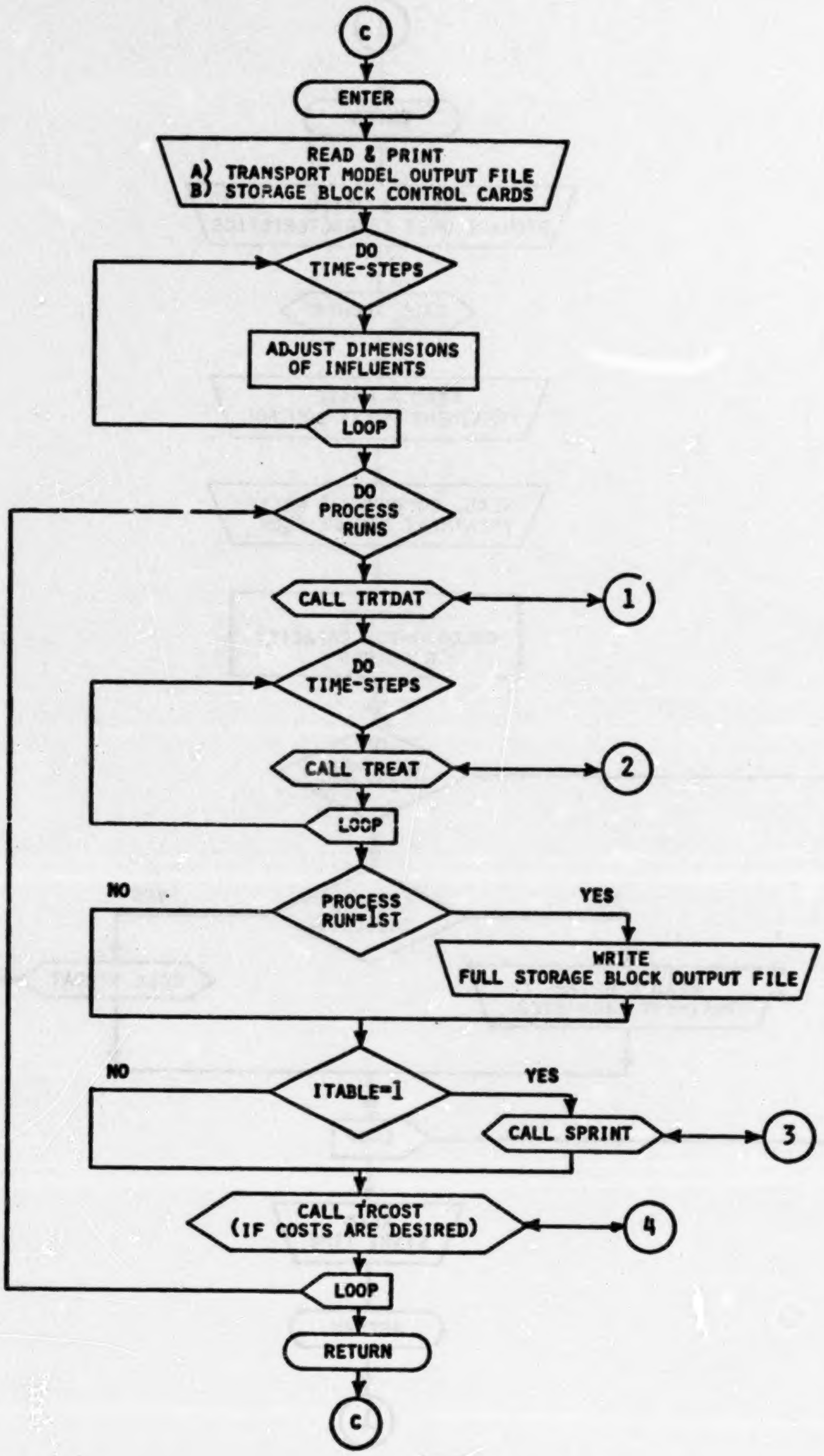

C
ENTER
READ & PRINT
A) TRANSPORT MODEL OUTPUT FILE
B) STORAGE BLOCK CONTROL CARDS
DO TIME-STEPS
ADJUST DIMENSIONS OF INFLUENTS
LOOP
DO PROCESS RUNS
CALL TRTDAT
1
DO TIME-STEPS
CALL TREAT
2
LOOP
NO
PROCESS RUN=1ST
YES
WRITE FULL STORAGE BLOCK OUTPUT FILE
NO
ITABLE=1
YES
CALL SPRINT
3
CALL TRCOST (IF COSTS ARE DESIRED)
4
LOOP
RETURN
C

Figure 5-3. SUBROUTINE STORAG

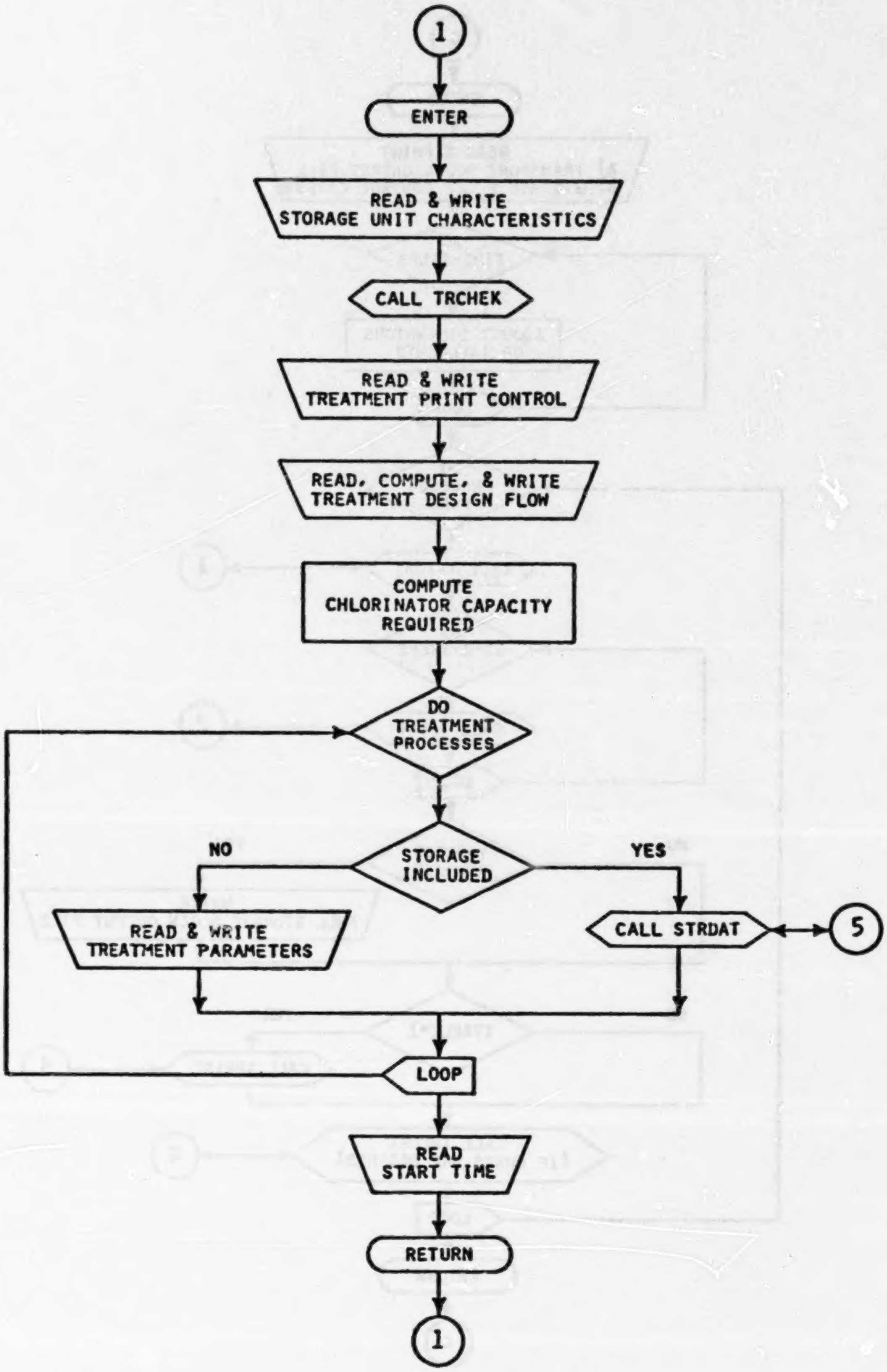

1
ENTER
READ & WRITE STORAGE UNIT CHARACTERISTICS
CALL TRCHEK
READ & WRITE TREATMENT PRINT CONTROL
READ, COMPUTE, & WRITE TREATMENT DESIGN FLOW
COMPUTE CHLORINATOR CAPACITY REQUIRED
DO TREATMENT PROCESSES
STORAGE INCLUDED
NO
YES
READ & WRITE TREATMENT PARAMETERS
CALL STRDAT
5
LOOP
READ START TIME
RETURN
1

Figure 5-4. SUBROUTINE TRTDAT

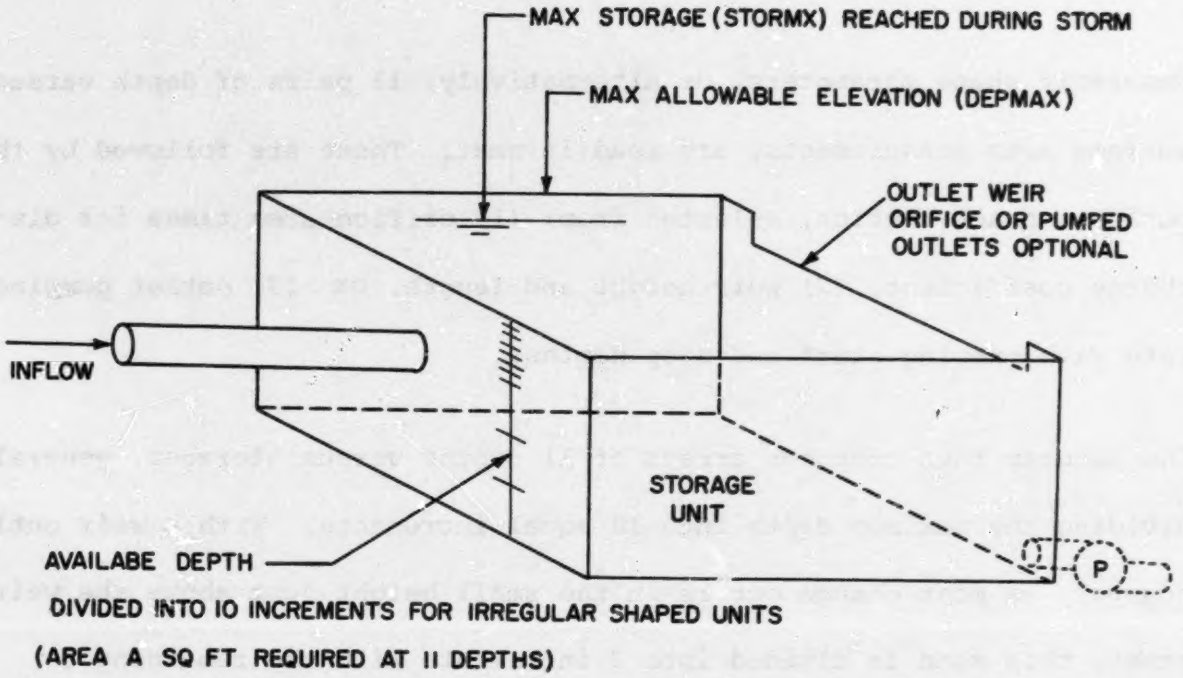

MAX STORAGE (STORMX) REACHED DURING STORM
MAX ALLOWABLE ELEVATION (DEPMAX)
OUTLET WEIR
ORIFICE OR PUMPED
OUTLETS OPTIONAL
INFLOW
STORAGE
UNIT
P
AVAILABE DEPTH
DIVIDED INTO 10 INCREMENTS FOR IRREGULAR SHAPED UNITS
(AREA A SQ FT REQUIRED AT 11 DEPTHS)

Figure 5-5. DIAGRAMMATIC SKETCH OF STORAGE UNITS

Parameters specifying alternative characteristics, such as irregular or geometric shape, and outflow control by gravity flow through an orifice or over a weir, or by pumping, are read in first.

The maximum permissible water depth is read in next. Subsequent inflows are partially bypassed if they would otherwise cause the storage depth to exceed this value.

Reservoir shape parameters, or alternatively, 11 pairs of depth versus surface area measurements, are read in next. These are followed by the outlet characteristics, selected from: (1) orifice area times its discharge coefficient, (2) weir height and length, or (3) outlet pumping rate with pumping start and stop depths.

The program then computes arrays of 11 depths versus storages, generally dividing the maximum depth into 10 equal increments. With a weir outlet, however, as most change occurs in the small height just above the weir crest, this zone is divided into 7 increments with the remaining 3 larger increments below the crest.

For gravity outflows, 11 pairs of routing parameters are computed from the storage and the outlet control selected. For pumped outflows, the "buffer" volume in storage between pump start and stop depths is computed and compared with the volume capable of being pumped out each time-step. Warning messages will be written if this comparison is not favorable.

Finally, initial storage and outflow conditions of the reservoir are read in. An outline flow chart of subroutine STRDAT is shown in Figure 5-6.

Subroutine TREAT ②

This subroutine is the heart of the Treatment model. It computes the movements and removals of water and pollutants on a process-by-process basis, every time-step. The various process characteristics specified earlier by subroutine TRTDAT are used.

If treatment by settling in new sedimentation tanks, or by high rate filters, is specified, then subroutine SEDIM or HIGHRF, respectively, is called into play. Where chlorination is specified, subroutine KILL models the reduction in coliform counts.

When a storage unit is included in this Block, subroutine TREAT calls upon subroutine STRAGE to model the movements within storage. In this case sedimentation within storage is modeled at the same time.

Depending upon the print control specified in subroutine TRTDAT, this subroutine may print out reports on intermediate progress and summaries of removal performances. An outline flow chart of subroutine TREAT is shown in Figure 5-7.

Subroutine STRAGE ⑥

Subroutine STRAGE is the heart of the Storage model. When a storage unit is included in the model, it computes the movements of water and pollutants through the unit every time-step. The various basin characteristics computed earlier by STRDAT are used.

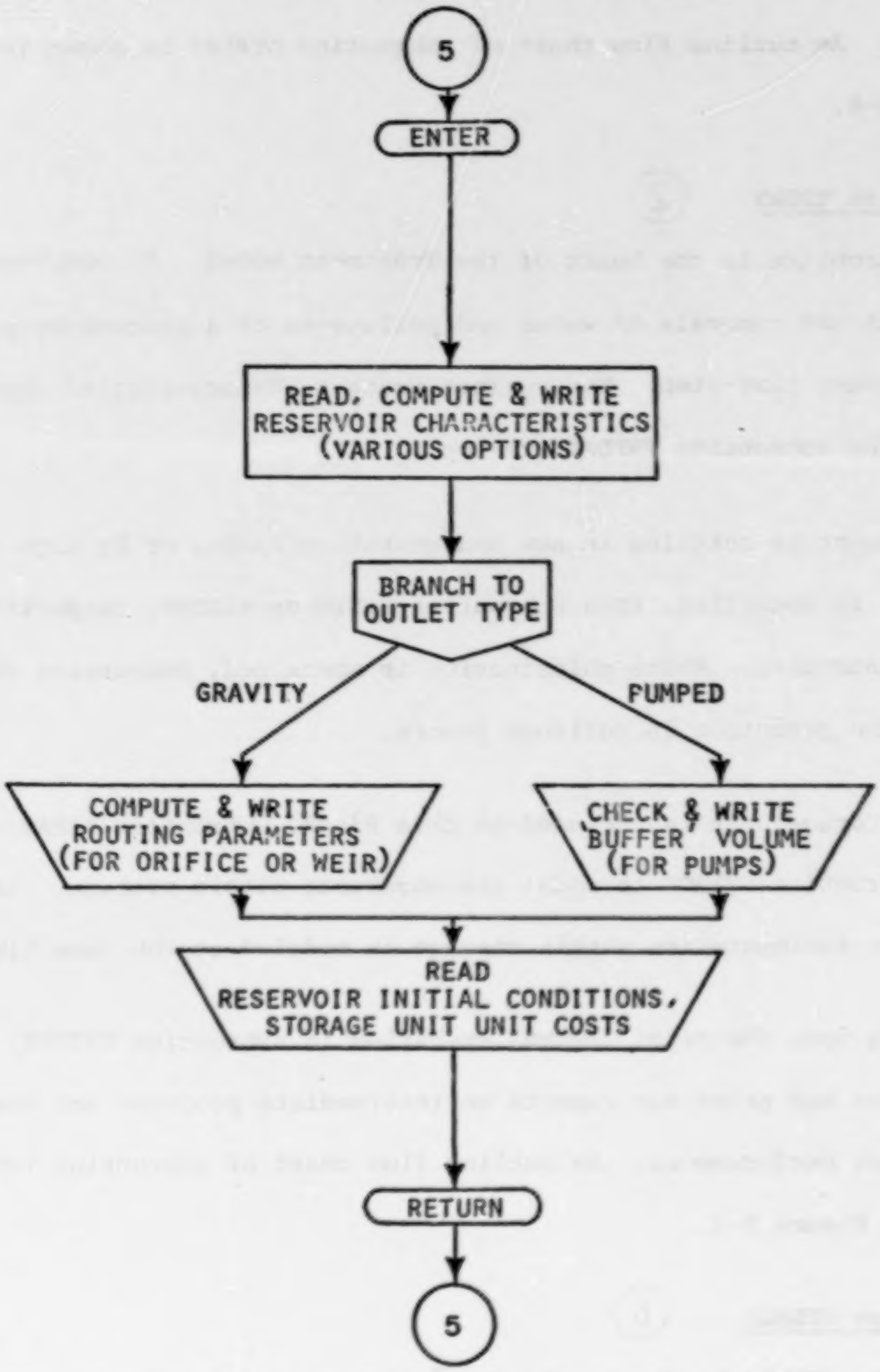

5
ENTER
READ, COMPUTE & WRITE RESERVOIR CHARACTERISTICS (VARIOUS OPTIONS)
BRANCH TO OUTLET TYPE
GRAVITY
PUMPED
COMPUTE & WRITE ROUTING PARAMETERS (FOR ORIFICE OR WEIR)
CHECK & WRITE 'BUFFER' VOLUME (FOR PUMPS)
READ RESERVOIR INITIAL CONDITIONS, STORAGE UNIT UNIT COSTS
RETURN
5

Figure 5-6. SUBROUTINE STRDAT

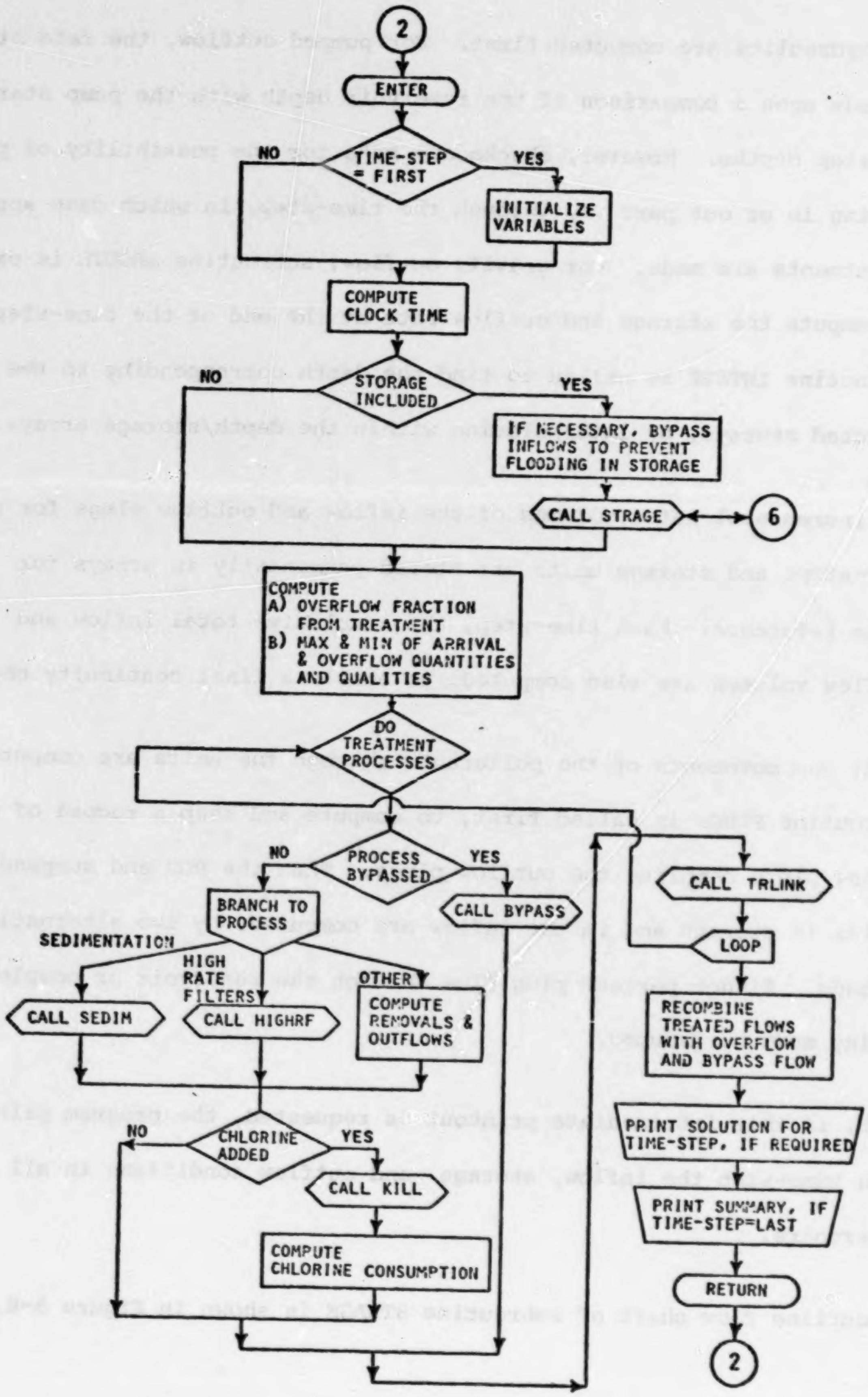

2
ENTER
TIME-STEP = FIRST
NO
YES
INITIALIZE VARIABLES
COMPUTE CLOCK TIME
STORAGE INCLUDED
NO
YES
IF NECESSARY, BYPASS INFLOWS TO PREVENT FLOODING IN STORAGE
CALL STRAGE
6
COMPUTE
A) OVERFLOW FRACTION FROM TREATMENT
B) MAX & MIN OF ARRIVAL & OVERFLOW QUANTITIES AND QUALITIES
DO TREATMENT PROCESSES
PROCESS BYPASSED
NO
YES
BRANCH TO PROCESS
CALL BYPASS
SEDIMENTATION
HIGH RATE FILTERS
OTHER
CALL SEDIM
CALL HIGHRF
COMPUTE REMOVALS & OUTFLOWS
CHLORINE ADDED
NO
YES
CALL KILL
COMPUTE CHLORINE CONSUMPTION
CALL TRLINK
LOOP
RECOMBINE TREATED FLOWS WITH OVERFLOW AND BYPASS FLOW
PRINT SOLUTION FOR TIME-STEP, IF REQUIRED
PRINT SUMMARY, IF TIME-STEP=LAST
RETURN
2

Figure 5-7. SUBROUTINE TREAT

The hydraulics are computed first. For pumped outflow, the rate simply depends upon a comparison of the reservoir depth with the pump start and stop depths. However, checks are made for the possibility of pumps cutting in or out part way through the time-step, in which case appropriate adjustments are made. For gravity outflow, subroutine SROUTE is called to compute the storage and outflow rate at the end of the time-step. Subroutine INTERP is called to find the depth corresponding to the computed storage, by interpolation within the depth/storage arrays.

The incremental water volumes of the inflow and outflow plugs for all time-steps and storage units are stored permanently in arrays for later reference. Each time-step, the cumulative total inflow and outflow volumes are also computed, to enable a final continuity check.

Next, the movements of the pollutants through the units are computed. Subroutine PLUGS is called first, to compute and keep a record of which inflow plugs comprise the outflow plugs. Then the BOD and suspended solids in storage and in the inflow are computed, by two alternative methods. Either perfect plug flow through the reservoir or complete mixing must be assumed.

Last, if this intermediate printout is requested, the program prints each time-step the inflow, storage and outflow conditions in all reservoirs.

An outline flow chart of subroutine STRAGE is shown in Figure 5-8.

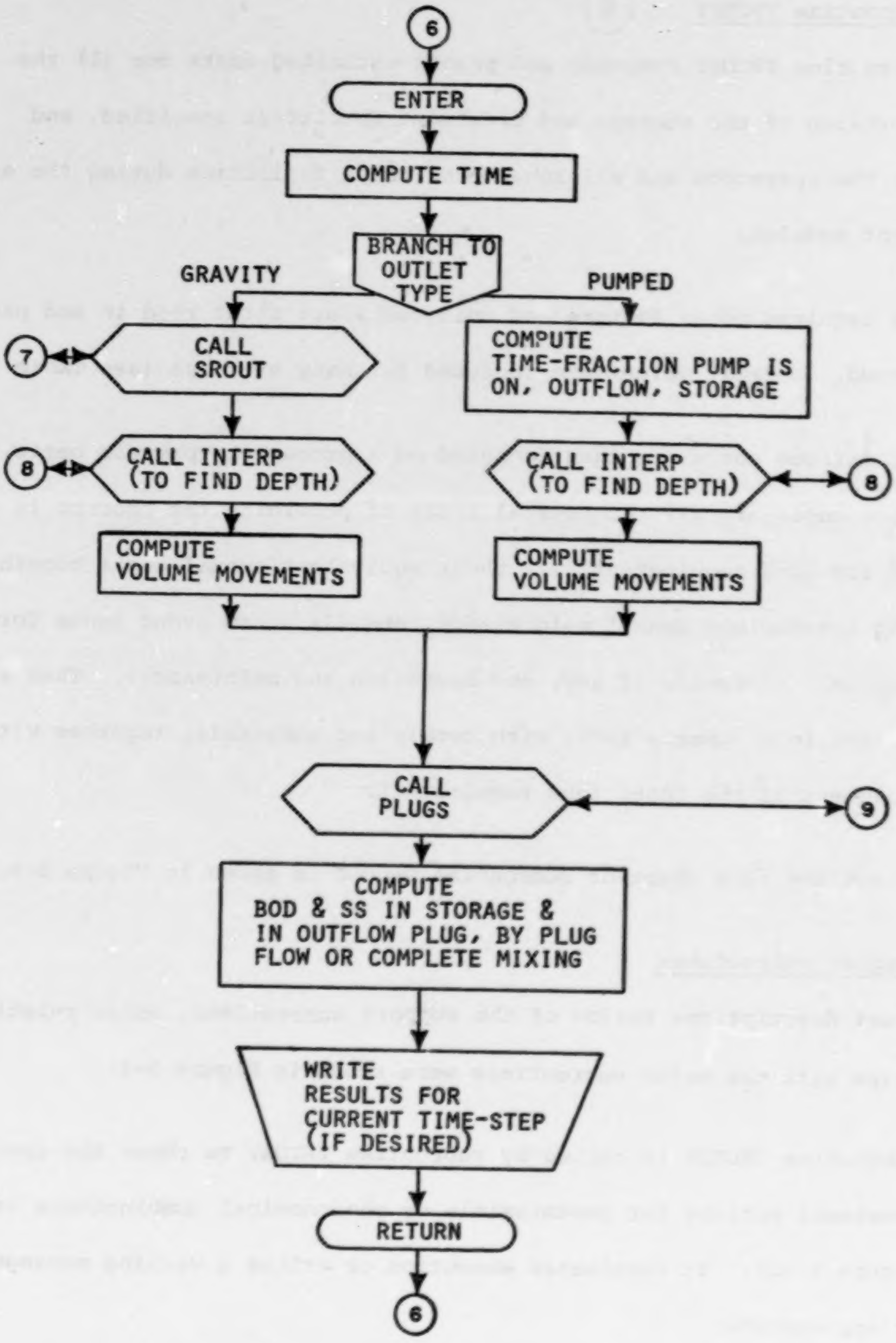

6
ENTER
COMPUTE TIME
BRANCH TO OUTLET TYPE
GRAVITY
PUMPED
7
CALL SROUT
COMPUTE TIME-FRACTION PUMP IS ON, OUTFLOW, STORAGE
8
CALL INTERP (TO FIND DEPTH)
CALL INTERP (TO FIND DEPTH)
8
COMPUTE VOLUME MOVEMENTS
COMPUTE VOLUME MOVEMENTS
CALL PLUGS
9
COMPUTE BOD & SS IN STORAGE & IN OUTFLOW PLUG, BY PLUG FLOW OR COMPLETE MIXING
WRITE RESULTS FOR CURRENT TIME-STEP (IF DESIRED)
RETURN
6

Figure 5-8. SUBROUTINE STRAGE

Subroutine TRCOST ④

Subroutine TRCOST computes and prints estimated costs for (1) the provision of the storage and treatment facilities specified, and (2) the operation and maintenance of these facilities during the storm event modeled.

The required money factors and unit costs are first read in and processed. Default values are included for many of these (see Table 5-1).

The various costs are then computed on a process-by-process basis. These costs are (1) the capital costs of providing the process in question and its land requirement, (2) their equivalent annual costs together with irreducible annual maintenance, and (3) storm event costs for chemicals consumed, if any, and operation and maintenance. They are printed in a summary table with totals and subtotals, together with a statement of the total land requirement.

An outline flow chart of subroutine TRCOST is shown in Figure 5-9.

Support Subroutines

Brief descriptions follow of the support subroutines, whose relationships with the major subroutines were shown in Figure 5-1.

Subroutine TRCHEK is called by subroutine TRTDAT to check the specified treatment options for inadmissible or uneconomical combinations (see Figure 5-10). It terminates execution or writes a warning message as appropriate.

Table 5-1. DEFAULT VALUES USED IN SUBROUTINE TRCOST

Item	Default Value
Interest rate	7%
Amortization period	25 yr
Site factors	1.00
Unit cost land	$20,000/acre
Unit cost power	2¢/kwh
Unit cost chlorine	20¢/lb
Unit cost polymers	$1.25/lb
Unit cost alum	3¢/lb
Storage construction unit cost (excavation, lining, etc.)	$3.00/cy

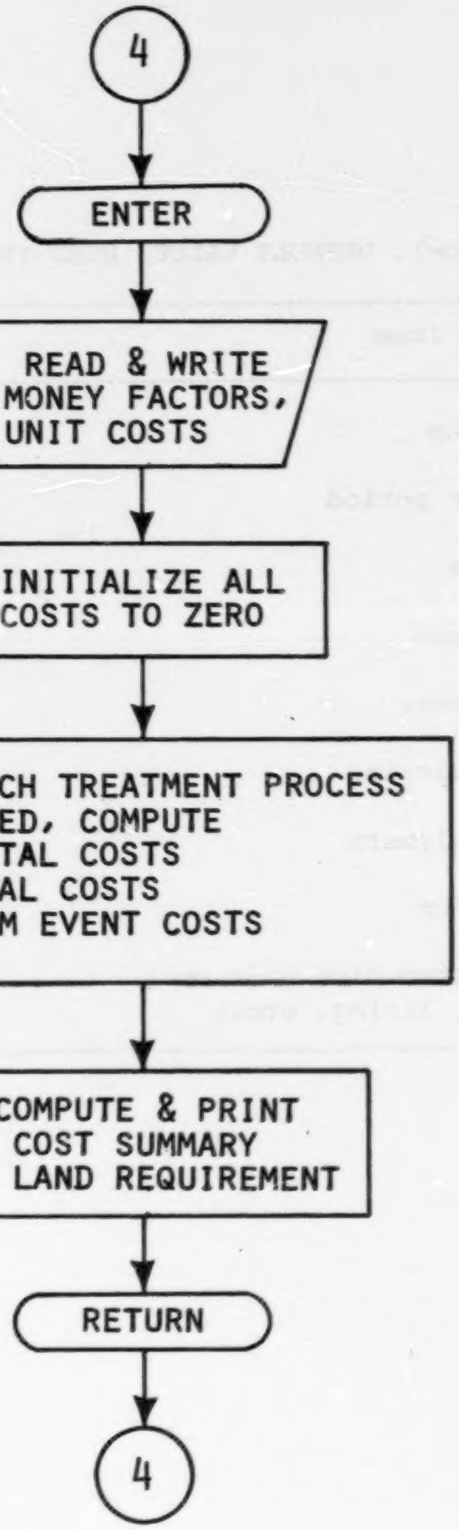
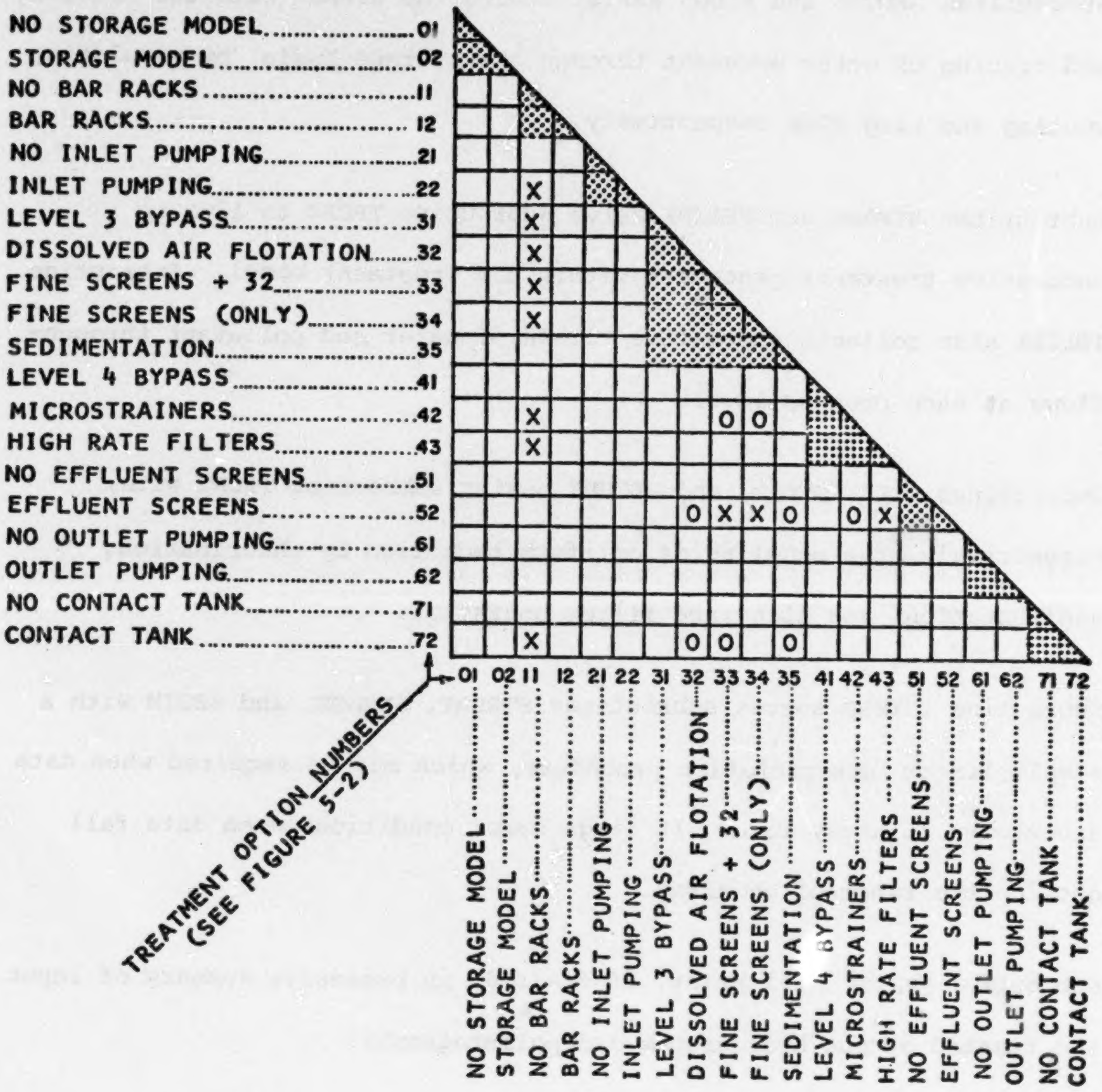

4
ENTER
READ & WRITE
MONEY FACTORS,
UNIT COSTS
INITIALIZE ALL
COSTS TO ZERO
FOR EACH TREATMENT PROCESS
INCLUDED, COMPUTE
CAPITAL COSTS
ANNUAL COSTS
STORM EVENT COSTS
COMPUTE & PRINT
A) COST SUMMARY
B) LAND REQUIREMENT
RETURN
4

Figure 5-9. SUBROUTINE TRCOST



	01	02	11	12	21	22	31	32	33	34	35	41	42	43	51	52	61	62	71	72
NO STORAGE MODEL 01	▨																			
STORAGE MODEL 02	▨	▨																		
NO BAR RACKS 11			▨																	
BAR RACKS 12			▨	▨																
NO INLET PUMPING 21					▨															
INLET PUMPING 22			X		▨	▨														
LEVEL 3 BYPASS 31			X				▨													
DISSOLVED AIR FLOTATION 32			X				▨	▨												
FINE SCREENS + 32 33			X				▨	▨	▨											
FINE SCREENS (ONLY) 34			X				▨	▨	▨	▨										
SEDIMENTATION 35							▨	▨	▨	▨	▨									
LEVEL 4 BYPASS 41												▨								
MICROSTRAINERS 42			X						O	O		▨	▨							
HIGH RATE FILTERS 43			X									▨	▨	▨						
NO EFFLUENT SCREENS 51															▨					
EFFLUENT SCREENS 52								O	X	X	O		O	X	▨	▨				
NO OUTLET PUMPING 61																	▨			
OUTLET PUMPING 62																	▨	▨		
NO CONTACT TANK 71																			▨	
CONTACT TANK 72			X					O	O		O								▨	▨

LEGEND

▨ .... COMBINATIONS IMPOSSIBLE DUE TO THE STRUCTURE OF THE PROGRAM

☒ .... INADMISSIBLE COMBINATIONS

O .... UNECONOMICAL COMBINATIONS

Figure 5-10. INADMISSIBLE AND UNECONOMICAL TREATMENT OPTIONS

Subroutines SROUTE and PLUGS assist subroutine STRAGE with the modeling and tracing of water movement through the storage basin, by simulating routing and plug flow respectively.

Subroutines BYPASS and TRLINK serve subroutine TREAT to link up successive treatment processes within the Treatment model. Subroutine TRLINK also collects cumulative totals of water and pollutant throughflows at each process level.

Subroutines KILL, SEDIM, and HIGHRF assist subroutine TREAT with, respectively, the modeling of coliform reduction by chlorination, sedimentation, and high rate filter operation.

Subroutine INTERP serves subroutines STRDAT, STRAGE, and SEDIM with a simple linear interpretation procedure, which may be required when data are stored in array form. It flags error conditions when data fall outside the range of an array.

Subroutine SPRINT will print, if desired, an extensive summary of input and treated output hydrographs and pollutographs.

Outline flow charts of subroutines SROUTE, PLUGS, and INTERP are shown, respectively, in Figures 5-11, 5-12 and 5-13.

INSTRUCTIONS FOR DATA PREPARATION

Instructions for data preparation for the Storage Block have been divided along the lines of the major components for clarity of the presentation. These components are: Storage, Treatment, and Cost. Programming options permit the deletion of the cost and/or storage routines;

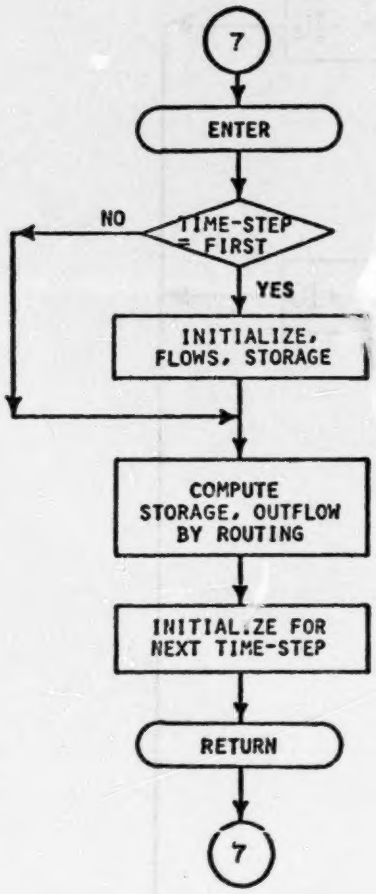

7
ENTER
NO
TIME-STEP = FIRST
YES
INITIALIZE, FLOWS, STORAGE
COMPUTE STORAGE, OUTFLOW BY ROUTING
INITIALIZE FOR NEXT TIME-STEP
RETURN
7

Figure 5-11. SUBROUTINE SROUTE

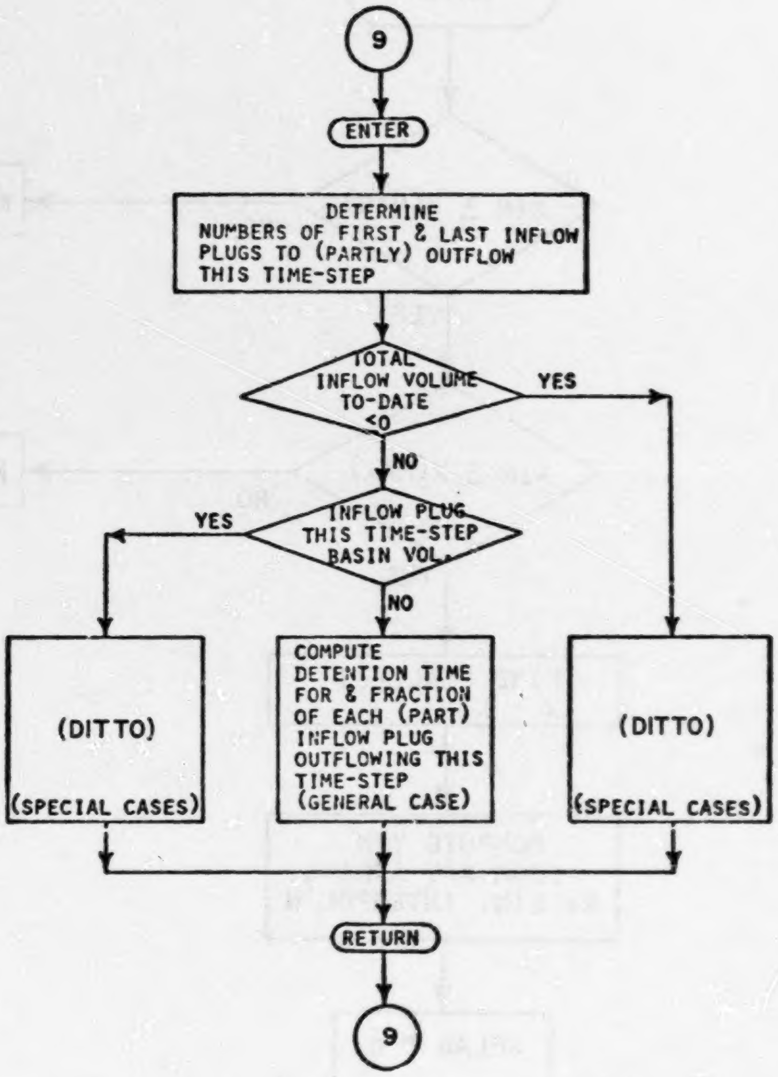

9
ENTER
DETERMINE NUMBERS OF FIRST & LAST INFLOW PLUGS TO (PARTLY) OUTFLOW THIS TIME-STEP
TOTAL INFLOW VOLUME TO-DATE <0
YES
NO
INFLOW PLUG THIS TIME-STEP BASIN VOL.
YES
NO
(DITTO)
(SPECIAL CASES)
COMPUTE DETENTION TIME FOR & FRACTION OF EACH (PART) INFLOW PLUG OUTFLOWING THIS TIME-STEP (GENERAL CASE)
(DITTO)
(SPECIAL CASES)
RETURN
9

Figure 5-12. SUBROUTINE PLUGS

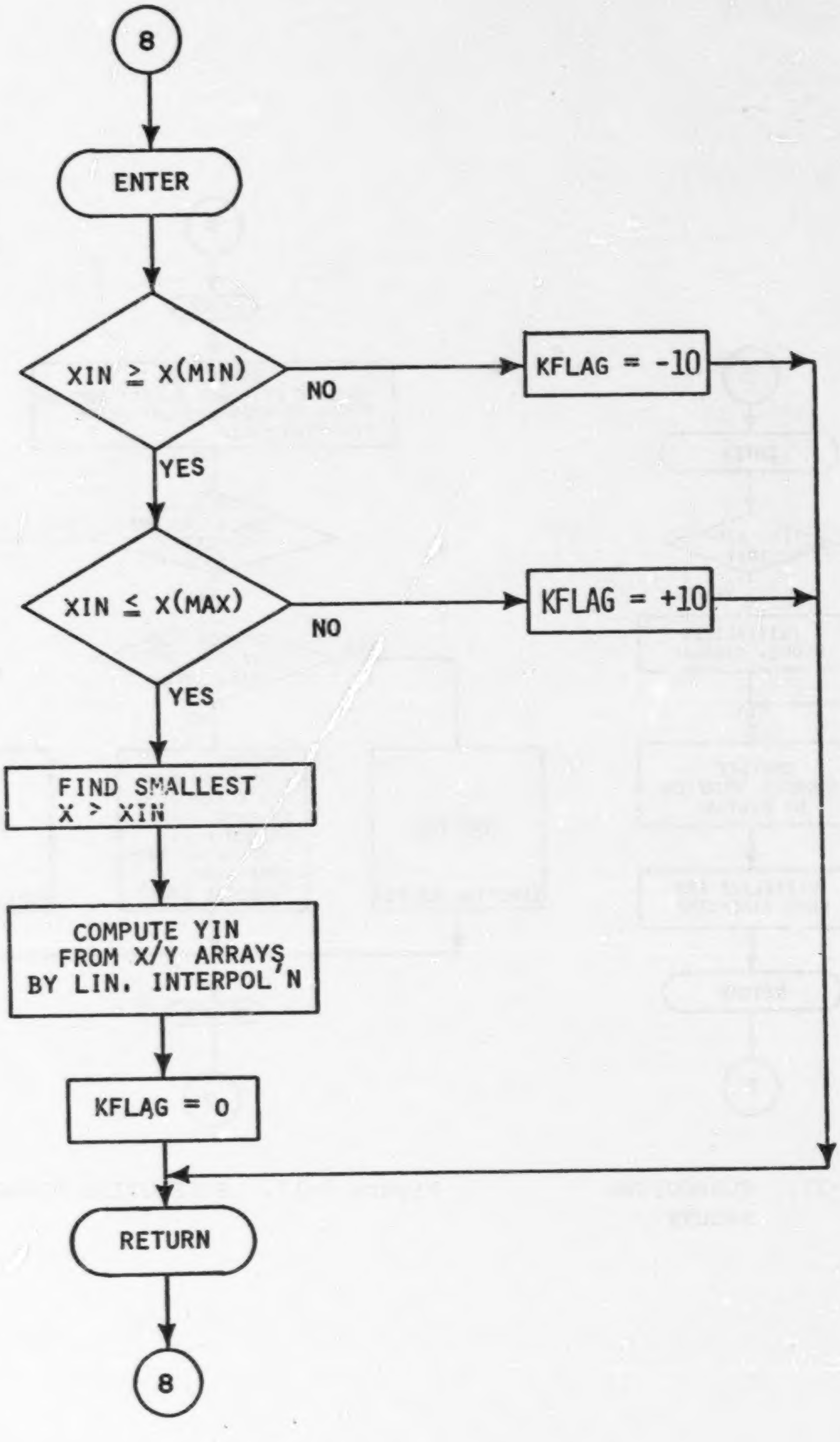

8
ENTER
XIN ≥ X(MIN)
NO
KFLAG = -10
YES
XIN ≤ X(MAX)
NO
KFLAG = +10
YES
FIND SMALLEST X > XIN
COMPUTE YIN FROM X/Y ARRAYS BY LIN. INTERPOL'N
KFLAG = 0
RETURN
8

Figure 5-13. SUBROUTINE INTERP

however, some form of treatment must be specified once the Block is called. The typical data deck setup for the complete Storage Block is shown in Figure 5-14. Storage data describe the physical characteristics of the storage system and controls. Treatment data specify the treatment string sequence and provide supplemental data based upon the processes selected. Cost data describe locations and years to be simulated and provide unit costs.

Data card preparation and sequencing instructions for the complete Storage Block are given at the end of these instructions in Table 5-2 followed by an alphabetical listing of the variable names and descriptions in Table 5-3.

Programming Limitations

The following programming limitations apply to the Storage Block:

1. Maximum number of time-steps = 150.
2. Maximum number of pollutants = 3 and these must be BOD, SS, and coliforms.
3. Maximum number of Transport Model outfalls (Transport Block output files) = 5, any one of which may be called for Storage Block operations.
4. Maximum number of Transport Model outfalls to be treated in a single run = 1.
5. Maximum number of points of chlorine application in Treatment = 1.
6. When treatment by high rate filters is included the only permissible time-step size = 0.5, 1.0, 2.0, 2.5, 5.0, or 10.0 minutes.

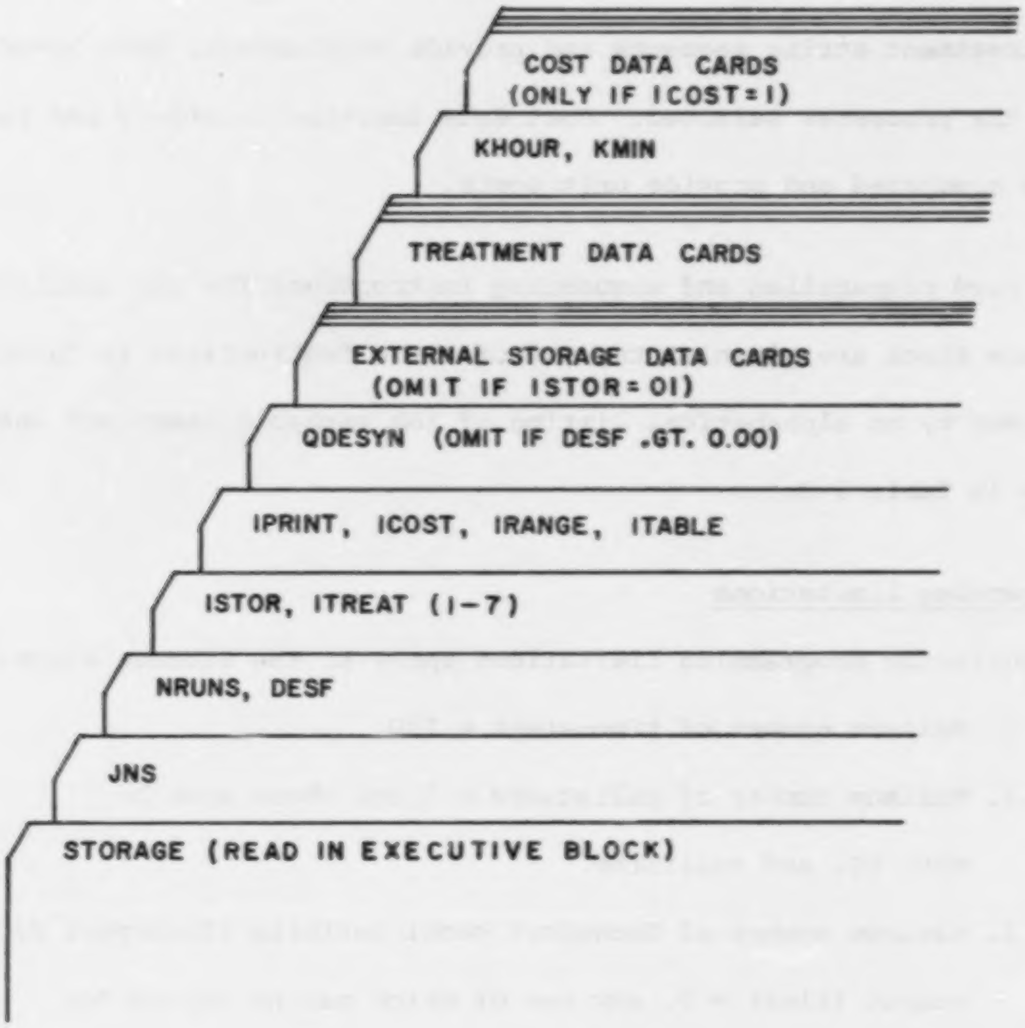

COST DATA CARDS
(ONLY IF ICOST=1)
KHOUR, KMIN
TREATMENT DATA CARDS
EXTERNAL STORAGE DATA CARDS
(OMIT IF ISTOR=01)
QDESYN (OMIT IF DESF .GT. 0.00)
IPRINT, ICOST, IRANGE, ITABLE
ISTOR, ITREAT (1-7)
NRUNS, DESF
JNS
STORAGE (READ IN EXECUTIVE BLOCK)

Figure 5-14. DATA DECK FOR STORAGE BLOCK

Storage Model

Use of the External Storage Model involves seven basic steps.

Step 1 - Flow and Quality Input. Rewind and read the Transport output file. Specify the external element number of the outfall to be treated, the number of complete runs through treatment desired (generally one), and the design flow. In addition to the hydrographs and pollutographs, data are read from the tape listing the number and size of time-steps, time zero, and the total tributary area.

Step 2 - Storage-Treatment String. Set ISTOR = 02 and specify treatment string (see instructions under Treatment model below for option selection). Option 35 = Sedimentation must be used if an external storage unit is to be modeled.

Step 3 - Output. Select output and computational options according to the following:

```
IPRINT = 0 = NO PRINTOUT EACH TIME-STEP (SUMMARY POSSIBLE)
       = 1 = PRINTOUT SOLUTION EACH TIME-STEP (QUANTITY)
       = 2 = PRINTOUT SOLUTION EACH TIME-STEP (QUALITY)
ICOST  = 0 = NO COST COMPUTATIONS AND SUMMARY
       = 1 = COMPUTE COSTS AND SUMMARIZE
IRANGE = 0 = QUANTITY RANGES (MAX,AV,MIN) NOT SUMMARIZED
       = 1 = QUANTITY RANGES (MAX,AV,MIN) SUMMARIZED
ITABLE = 0 = INFLOWS,OUTFLOWS NOT SUMMARIZED IN FINAL TABLES
       = 1 = INFLOWS AND OUTFLOWS SUMMARIZED IN FINAL TABLES
```

Step 4 - Storage Unit. Describe the storage unit mode (in-line); construction (natural, manmade and covered, manmade and uncovered); type of outlet device (orifice, weir, or pumped); routing (plug flow or complete mixing); and basin parameters.

Step 5 - Unit Cost. Specify the storage basin unit cost ($ per cubic yard of maximum storage capacity) to be used to represent excavation, lining, cover, and appurtenances.

Step 6 - Treatment and Treatment Cost Data. Furnish supplemental data based upon the treatment options selected (see instructions under Treatment model and Cost model).

Step 7 - Starting Time. Furnish the clock time of the start of the simulation.

Treatment Model

The steps in data preparation for use in the Treatment model follow the same sequence as that listed for the Storage model. Steps 1, 3, 6, and 7 are identical to the Storage model. If external storage is omitted (by setting ISTOR=01 in Step 2), Steps 4 and 5 are deleted. An extension of the discussion of Steps 2 and 6 follows.

Step 2 - Storage-Treatment String. In setting up a treatment string, all seven levels (see Figure 5-2) must be specified. The first digit in each option identified represents the computation level, and the second digit represents the path on that level. If the bypass of certain levels is requested (i.e., no treatment on that computational level), this condition is specified by setting the path indicator equal to 1. Similarly, if the path indicator is other than 1, some treatment will be performed. For example, if a treatment string is to represent a plant providing bar racks, microstrainers, and chlorination, and nothing else, the appropriate specification would be:

01-12-21-31-42-51-61-72

Step 6 - Treatment and Treatment Cost Data. Only certain treatment options require supplemental data input. These options are:

Inlet and/or outlet pumping

Dissolved air flotation

Sedimentation

High rate filters.

The pumping options require that the total pumping head be given (for computation of operating costs). The dissolved air flotation units require specifications regarding polymer use, chlorine use, design overflow rate, recirculation flow, and tank depth. Similarly, sedimentation tanks require overflow rates, tank depths, and chlorine use. High rate filters require that the maximum operating rate, chemical addition, maximum design head loss, and maximum solids holding capacity (at maximum head and maximum flow rate) be specified. Detailed instructions are given in Table 5-2.

Cost Model

The cost model is called by setting ICOST=1 in Step 3. The cost data cards follow the supplemental treatment data cards in Step 6.

The first card sets the interest rate, the useful life expectancy of the equipment, the year to be modeled, and the city to which costs are to be adjusted. The city cost factor is the ratio of that city's ENR

(Engineering News Record Construction Cost Index) average to the national average.

Next, ENR Cost Indexes expected to prevail in each of the next 10 years are read in. Finally, the general unit costs for land, power, chlorine, polymers, and alum are read. A summary of these cost parameters and their units follows (default values were listed in Table 5-1).

UCLAND = UNIT COST OF LAND, $/ACRE
UCPOWR = UNIT COST OF POWER, $/KWH
UCCL2 = UNIT COST OF CHLORINE, $/LB
UCPOLY = UNIT COST OF POLYMERS, $/LB
UCALUM = UNIT COST OF ALUM, $/LB
RATEPC = INTEREST RATE FOR AMORTIZATION, PERCENT
NYRS = AMORTIZATION PERIOD, YEARS
MODYR = YEAR OF MODEL, FOR COSTS
SITEF = AN ENR FACTOR FOR GEOGRAPHIC LOCATION OF SITE

Table 5-2. STORAGE BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	I10	1-10	External element number from the Transport Block (NOUTS) which routes the flow to the Storage Block (maximum = 1 for each run).	JNS	none
2			Execution Control Data		
	I10	1-10	Number of different treatment executions to be made on the output from the Transport Block, element JNS.	NRUNS	
	F10.2	11-20	The ratio of the maximum flow to be treated to the maximum flow arriving.	DESF	QDESYN*
3			Treatment Control Data		
	10I5	1-5	Parameter indicating if external storage is to be called. ISTOR = 1, External storage not called, ISTOR = 2, Flow routed through external storage.	ISTOR	none
		6-10	Bar rack treatment parameter (level 1) = 11, Bar racks are not used or are bypassed, = 12, Bar racks are in the waste stream.	ITREAT(1)	none
		11-15	Inlet pumping parameter (level 2) = 21, No pump station, = 22, Pump station exists.	ITREAT(2)	none
		16-20	Primary treatment parameter (level 3) = 31, No primary treatment (flow bypassed), = 32, Dissolved air flotation, = 33, Fine screens and dissolved air flotation, = 34, Fine screens only, = 35, Sedimentation.	ITREAT(3)	none
		21-25	Secondary treatment parameter (level 4) = 41, No secondary treatment (flow bypassed), = 42, Microstrainers, = 43, High rate filter.	ITREAT(4)	none
		26-30	Effluent screens (level 5) = 51, No screens, = 52, Effluent screens.	ITREAT(5)	none

---

*See card group 5.

NOTE: All non-decimal numbers must be right-justified.

Table 5-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		31-35	Outlet pumping parameter (level 6) = 61, No pumping, = 62, Pumping required.	ITREAT(6)	none
		36-40	Chlorine contact tank (level 7) = 71, No chlorine contact tank (flow bypassed), = 72, Chlorine contact tank.	ITREAT(7)	none
4			Computation Print Control Card		
	4I10	1-10	Printout of treatment results for each time-step. = 0, Printout for each time-step suppressed, = 1, Printout quantity results for each time-step, = 2, Printout quality results for each time-step.	IPRINT	0
		11-20	Cost control data = 0, Cost calculations and the resulting printout are suppressed, = 1, Compute costs and print cost summary.	ICOST	0
		21-30	Flow quantities summarization control parameter = 0, Flow quantity ranges not summarized, = 1, Quantity ranges summarized.	IRANGE	0
		31-40	Control of tabular output of the inlet and outlet flows from the treatment model. = 0, Flows not summarized in tabular form, = 1, Flows summarized in tabular form.	ITABLE	
			IF DESF IN CARD GROUP 2 IS ZERO INCLUDE CARD GROUP 5, OTHERWISE OMIT		
5	F10.2	1-10	Design flow rate of treatment facilities (cfs).	QDESYN	none
			CARDS 6 THROUGH 15 ARE DATA INPUT FOR EXTERNAL STORAGE. (ISTOR = 2). OMIT THESE DATA CARDS IF EXTERNAL STORAGE IS NOT DESIRED.		
6			Storage unit data card.		
	10I5	1-5*	Storage mode parameter. = 1, In-line storage.	ISTMOD	none

---

*Must be set equal to one since other storage mode parameters are not programmed.

Table 5-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		6-10	Storage type parameter.	ISTTYP	none
			= 1, Irregular (natural) reservoir,		
			= 2, Geometric (regular) covered reservoir,		
			= 3, Geometric (regular) uncovered reservoir.		
		11-15	Storage outlet control parameter.	ISTOUT	none
			= 1, Gravity with orifice center line at zero storage tank depth,		
			= 2, Gravity with fixed weir,		
			= 6, Existing fixed-rate pumps,		
			= 9, Gravity with both weir and orifice.*		
7			Computation/print control card.		
	3I10	1-10	Basin flow parameter.	IPOL	none
			= 1, Perfect plug flow through basin,		
			= 2, Perfect mixing in basin.		
		11-20	Print control parameter	ISPRIN	none
			= 0, No print each time-step,		
			= 1, Print each time-step in storage.		
8			Reservoir flood depth data card.		
	F10.2	1-10	Maximum (flooding) reservoir depth.	DEPMAX	none
	I10	11-20	Chlorination option.**	ICL2	none
			INCLUDE EITHER CARD GROUP 9 OR 10, NOT BOTH.		
			INCLUDE CARD GROUP 9 ONLY IF ISTTYP ON CARD 6 HAS THE VALUE 1.		
9			Reservoir depth-area data card (4(F10.2, F10.0)).		
	F10.2	1-10	A reservoir water depth.	ADEPTH(1)	none
	F10.0	11-20	Reservoir surface area corresponding to above depth.	AASURF(2)	none
	⋮			⋮	
	F10.2	61-70	A reservoir water depth.	ADEPTH(4)	none
	F10.0	71-80	Reservoir surface area corresponding to above depth.	AASURF(4)	
			(NOTE: The above pair of variables is repeated 11 times, 4 pairs per card.)		

---

*This type of storage outlet is not presently programmed.
**Not presently programmed, leave blank.

Table 5-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			INCLUDE CARD 10 ONLY IF ISTTYP ON CARD 6 HAS THE VALUE 2 OR 3.		
10			Reservoir dimensions data card.		
	2F10.0	1-10	Reservoir base area (sq ft).	BASEA	none
		11-20	Reservoir base circumference (ft).	BASEC	none
	F10.5	21-30	Cotan of sideslope (horizontal/vertical).	COTSLO	none
			INCLUDE ONLY ONE OF THE OUTLET DATA CARDS 11, 12, OR 13.		
			INCLUDE CARD 11 ONLY IF ISTOUT ON CARD 6 HAS THE VALUE 1.		
11			Orifice outlet data card.		
	F10.3	1-10	Orifice outlet area x discharge coefficient, sf.	CDAOUT	none
			INCLUDE CARD 12 ONLY IF ISTOUT ON CARD 6 HAS THE VALUE 2.		
12			Weir outlet data card.		
	2F10.3	1-10	Weir height (ft) above depth = 0.	WEIRHT	none
		11-20	Weir length (ft).	WEIRL	none
			INCLUDE CARD 13 ONLY IF ISTOUT ON CARD 6 HAS THE VALUE 6.		
13			Pump outlet data card.		
	3F10.3	1-10	Outflow pumping rate (cfs).	QPUMP	none
		11-20	Depth (ft) at pump startup.	DSTART	none
		21-30	Depth (ft) at pump shutdown	DSTOP	none
14			Initial conditions data card.		
	2F10.2	1-10	Storage (cf) at time zero.	STORO	none
		11-20	Outflow rate (cfs) at time zero.	QUOTO	none
15			Cost data card.		
	F10.2	1-10	$/cy for storage excavation.	CPCUYD	none
			END OF EXTERNAL STORAGE CARDS		

Table 5-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF ITREAT(2) = 22 INCLUDE CARD 16.		
16	F10.2	1-10	Pump head for inlet lift station of the treatment facilities (ft).	HEAD1	none
			INCLUDE ONLY ONE OF THE LEVEL 3 TREATMENT CARDS 17 OR 18 IF ITREAT(3) IS NOT EQUAL TO 31 OR 34.		
			INCLUDE CARD 17 ONLY IF ITREAT(3) ON CARD 3 HAS THE VALUE OF 32.		
17			Dissolved air flotation data cards.		
	2I5	1-5	Chemical addition to the unit.	ICHEM	0
			= 0, No chemical addition,		
			= 1, Chemical addition.		
		6-10	Chlorine addition to the unit.	ICL2	0
			= 0, No chlorine addition,		
			= 1, Chlorine addition.		
	3F10.2	11-20	Design overflow rate, gpd/sq ft (5,000.0 suggested).	OVRDAF	none
		21-30	Amount of flow recirculation (percent) (15% suggested).	RECIRC	none
		31-40	Depth of dissolved air flotation tank, ft.	DEEP	none
			INCLUDE CARD 18 IF ITREAT(3) = 35 AND ISTOR = 1 ON CARD 3.		
18			Primary sedimentation tank cards.		
	2F10.2	1-10	Primary sedimentation tank overflow rate, gpd/sq ft (1,600.0 suggested).	OVRSED	none
		11-20	Depth of sedimentation tank, ft (8.0 suggested).	SEDEP	
	I10	21-30	Chlorine addition to unit.	ICL2	0
			= 0, No chlorine addition,		
			= 1, Chlorine addition.		
			INCLUDE CARD 19 ONLY IF ITREAT(4) = 43.		
19			High rate filter data cards.		
	F10.2	1-10	Maximum operating rate of the filter, gpm/sq ft.	OPRAMA	none
	I10	11-20	Addition of chemicals.	ICHEMH	0
			= 0, No chemicals added,		
			= 1, Chemicals added.		

Table 5-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
	2F10.2	21-30	Maximum design head loss of filter (ft).	HM	none
		31-40	Maximum solids holding capacity at maximum head and maximum flow rate (lb/sq ft).	SQM	none
			INCLUDE CARD 20 ONLY IF ITREAT(6) = 62 ON CARD 3.		
20	F10.2	1-10	Pump head for outflow lift station from treatment facilities (ft).	HEAD2	none
			END OF TREATMENT CARDS.		
21			Time for start of treatment-storage simulation.		
	2I5	1-5	Hour of start, 24 hour clock.	KHOUR	none
		6-10	Minute of start (min).	KMIN	none
			INCLUDE CARDS 22 THROUGH 25 ONLY IF ICOST = 1 ON CARD 4.		
22			ENR Cost Data.		
	F10.2	1-10	Amortization interest rate for construction of treatment facilities (percent).	RATEPC	7.0
	2I10	11-20	Amortization period (yr).	NYRS	25
		21-30	Year of computer simulation (minimum = 1970, maximum = 1980).	MMDDYR	none
	F10.4	31-40	ENR factor for the geographic location of treatment facilities.	SITEF	1.00
23			ENR cost index for year and location.	IENR	
	8I10	1-10	ENR for 1970.	IENR(1)	none
		11-20	ENR for 1971.	IENR(2)	none
		⋮		⋮	
		71-80	ENR for 1977.	IENR(8)	none
		⋮		⋮	
		21-30	ENR for 1980.	IENR(11)	none
24			Unit cost data card.		
	F10.0	1-10	Unit cost of land ($/acre).	UCLAND	20000.00
	F10.5	11-20	Unit cost of power ($/KWH).	UCPOWR	0.02
	3F10.2	21-30	Unit cost of chlorine ($/lb).	UCCL2	0.20
		31-40	Unit cost of polymers ($/lb).	UCPOLY	1.25
		41-50	Unit cost of alum ($/lb).	UCALUM	0.03
			END OF STORAGE BLOCK CARDS.		

Table 5-3. STORAGE BLOCK VARIABLES

Variable Name	C*	Description	Unit
AASURF	C	Surface area of natural reservoir	sq ft
ADEPTH	C	Depth of reservoir	ft
ADJ		Dummy variable	
ALACST		Amortized cost of land required	$/yr
ALAND		Area of land required for this equipment	acres
ALANDT		Total area of land required for the equipment	acres
ALASC		Amortized cost of land required for screens	$/yr
ALCSTT		Total amortized cost of land required	$/yr
ALSC		Area of land required for screens	acres
ALUMUH		Alum used for high rate filter	lb
ALUMUT	C	Total alum used	lb
ANCSTT		Total amortized cost of installed equipment	$/yr
ANNSC		Amortized cost of screens	$/yr
ANNTOT		Total amortization cost including land and equipment	$
AO2DT2	C	Volume of outflow per half time-step	cf
APLAN	C	Land area requirement	sq ft
AREA		Surface area of man-made storage unit	sq ft
AREA1		Surface area for preceding time-step	sq ft
AREA2		Surface area for present time-step	sq ft
AREAMS	C	Submerged screen area	sq ft/unit
ATERM	C	Volume in storage plus outflow	cf
BACK		Back flow volume	cf
BASEA		Base area of reservoir	sq ft
BASEC		Base circumference of reservoir	ft
BASICM		Cost of minimum maintenance (no storm)	$/yr
BCIF		BOD concentration of inflow	mg/L
BCIFMN		Minimum BOD concentration of the inflow	mg/L
BCIFMX		Maximum concentration of BOD of inflow to the whole model	mg/L
BCIFT		Accumulative total or arithmetic average of BOD concentration of the inflow to the whole model	mg/L
BCIN	C	BOD inflow rate to one treatment unit	lb/DT
BCINMN		Minimum BOD concentration of the inflow	mg/L
BCINMX		Maximum BOD concentration of the inflow	mg/L
BCINT		Accumulative total or arithmetic average of BOD concentration of inflow to one treatment unit	mg/L
BCOF		BOD concentration in the bypass (overflow)	mg/L
BCOFMN		Minimum BOD concentration of the bypass (overflow)	mg/L
BCOFMX		Maximum BOD concentration of overflow	mg/L
BCOFT		Accumulative total or average of BOD concentration of the overflow	mg/L
BCOU	C	BOD concentration of outflow from one treatment unit per time-step	mg/L

---

*Variable names shared in common blocks.

Table 5-3 (continued)

Variable Name	C*	Description	Unit
BCOUFT		BOD concentration of outflow	mg/L
BCOUMN	C	Minimum BOD concentration of the outflow	mg/L
BCOUMX	C	Maximum concentration of BOD of outflow	mg/L
BCOUS		BOD concentration in the outflow from screens	mg/L
BCOUT	C	Accumulative total or arithmetic average of BOD concentration of outflow from one treatment level	mg/L
BCREDU		BOD concentration reduced	mg/L
BCRL		BOD concentration of the released flow per time-step	mg/L
BCRLMN		Minimum BOD concentration of the released flow	mg/L
BCRLMX		Maximum BOD concentration of the released flow	mg/L
BCRLT		Accumulated total or arithmetic average at BOD concentration of the released flow	mg/L
BCRM	C	BOD concentration of the waste flows from individual treatment unit	mg/L
BCRMMN	C	Minimum BOD concentration removed	mg/L
BCRMMX	C	Maximum BOD concentration removed	mg/L
BCRMT	C	Accumulative total for arithmetic average of BOD concentration of the wasted flows from one treatment unit	mg/L
BCRM1		BOD concentration of the waste flows from individual treatment unit	mg/L
BDARR	C	Outfall BOD	lb
BDCIF		BOD concentration of inflow (= BCIF)	mg/L

Variable Name	C*	Description	Unit
BDCRL		BOD concentration of released flow = BCRL	mg/L
BDEPTH	C	Water depth	ft
BDIF	C	Total BOD in the inflow to the whole model	lb
BDIFRF		Fraction of BOD removed to BOD flowing into whole model	
BDIFT		Accumulative total BOD of the inflow	lb
BDIN	C	BOD inflow rate to one treatment unit	lb/DT
BDINRF		Fraction of BOD removed to BOD flowing into each treatment unit	
BDINT	C	Accumulative total BOD flow into one treatment unit	lb
BDOF		BOD rate in bypassed waste flows	lb/DT
BDOFT		Accumulative total BOD in the overflows	lb
BDOU	C	BOD outflow rate	lb/DT
BDOUS		BOD outflow rate from screens	lb/DT
BDOUT	C	Accumulative total BOD flow out of one treatment unit	lb
BDRD		BOD reduction, percentage	%
BDRL	C	BOD released per time-step	lb/DT
BDRLT		Accumulative total BOD released from the whole model	lb
BDRM	C	BOD removal per time-step	lb/DT
BDRMT	C	Accumulative total BOD removal by one treatment unit	lb
BDRMIT		Accumulative total BOD removed by the whole model	lb

Table 5-3 (continued)

Variable Name	C*	Description	Unit
BDRS		BOD removed by screens per time-step	lb/DT
BDRST		Total BOD removed by screens	lb
BIG	C	Initializing number, (10^{12})	
BMSC		Basic maintenance cost of fine screens	$/storm
BODCOT		BOD outflow concentration	mg/L
BODIN	C	BOD inflow rate (pollutograph)	lb/DT
BODOUT	C	BOD outflow	lb
BREFF		BOD removal efficiency	
BREFFH	C	BOD removal efficiency of high rate filter	
BREFF2		BOD removal efficiency	
BSICMT		Total minimum maintenance cost	$
BSTOR	C	Storage	cf
BYPASS		Name of subroutine	
CAPCST		Capital cost of installed equipment	$
CAPMS		Capacity per microstrainer unit	mgd
CAPSC		Capital cost of screens	$
CAPST		Capital cost for five screens	$
CAPTOT		Total capital costs including land and equipment	$
CAPUCL		Dosing rate per trickling filter unit	lb/day
CCIF		Coliform concentration of inflow to whole model	MPN/100 ml
CCIFMN		Minimum coliform concentration of the inflow	MPN/100 ml
CCIFMX		Maximum coliform concentration of inflow	MPN/100 ml
CCIFT		Accumulative total for arithmetic average of coliform concentration of inflow	MPN/100 ml
CCIN		Coliform concentration of the inflow to one treatment unit	MPN/100 ml
CCINMN		Minimum coliform concentration of the inflow to one unit	MPN/100 ml
CCINMX		Maximum coliform concentration of the inflow to one unit	MPN/100 ml
CCINT		Accumulative total or arithmetic average of coliform concentration of the inflow to one treatment level	MPN/100 ml
CCOF		Coliform concentration in the overflow	MPN/100 ml
CCOFMN		Minimum coliform concentration of the overflow	MPN/100 ml
CCOFMX		Maximum coliform concentration of overflow	MPN/100 ml
CCOFT		Accumulative total for arithmetic average of coliform concentration of the overflow	MPN/100 ml
CCOU		Coliform concentration of the outflow during one time-step	MPN/100 ml
CCOUMN		Minimum coliform concentration of the outflows	MPN/100 ml
CCOUMX		Maximum coliform concentration of the outflow	MPN/100 ml
CCOUT		Accumulative total for arithmetic average of the outflow coliform concentration	MPN/100 ml
CCRL		Coliform concentration of the released flow per time-step	MPN/100 ml
CCRLMN		Minimum coliform concentration of the released flow	MPN/100 ml

Table 5-3 (continued)

Variable Name	C*	Description	Unit
CCRLMX		Maximum coliform concentration of the released flow	MPN/100 ml
CCRLT		Accumulative total or arithmetic average of coliform concentration of the released flow	MPN/100 ml
CDAOUT		Outlet orifice area times discharge coefficient	sq ft
CFSOF		Overflow rate for microstrainer	cfs
CFSTR		Internal bypass flow treated by microstrainer	cfs
CFSTR2		Effluent flow from microstrainer	cfs
CHCOST		Chemical cost, per process	$/storm
CHCSTT		Total chemical costs	$/storm
CHEMU		Chemical use per time-step and process	lb
CHEMUH		Chemical used for high rate filter	lb
CHEMUT	C	Total chemicals use per unit	lb
CLACST		Capital cost of land required	$
CLAND	C	Cost of lands	$
CLASC		Cost of land for screens	$
CLCSTT		Total capital cost of land requirement	$
CL2CST	C	Cost of chlorine used	$/storm
CL2DEM		Chlorine demand	mg/L
CL2U		Chlorine used per time-step	lb
CL2UC		Chlorine used	lb/day
CL2UT	C	Total chlorine used	lb/day

Variable Name	C*	Description	Unit
CL2UTT		Total chlorine used for whole model	lb
COARR	C	Outfall coliform	MPN
COCIF		Coliform concentration of inflow (= CCIF)	MPN/100 ml
COCRL		Coliform concentration of released flow (= CCRL)	MPN/100 ml
COIF	C	Coliform inflow rate for Storage Model	MPN/DT
COIFRF		Fraction of coliform removed to coliform flowing into the whole model	
COIFT		Accumulative total coliform inflow	MPN
COIN		Coliform inflow rate to one treatment unit	MPN/DT
COINRF		Fraction of coliform removed to coliform flowing into each treatment unit	
COINT		Accumulative total coliform flowing into one treatment unit	MPN
COLCOT		Coliform outflow	MPN/100 ml
COLIFT		Total coliform flowing into whole model	MPN
COLIN	C	Coliform inflow rate (pollutograph)	MPN/DT
COLOUT	C	Coliform outflow	MPN/DT
CONVER	C	Conversion factor 10^6/DT sec lbs/cf	mg/L/lb/cf
CONVOL		Volume of contact tank	cf
COOF		Number of coliform per time-step in the overflow	MPN/DT
COOFT		Accumulative total coliform in the overflow	MPN
COOU		Coliform outflow from one treatment unit per time-step	MPN/DT

Table 5-3 (continued)

Variable Name	C*	Description	Unit
COOUT		Accumulative total coliform flowing out of one treatment unit	MPN
CORD		Coliform reduction, percentage	%
CORL	C	Coliform released per time-step	MPN/DT
CORLT		Accumulative total coliform released	MPN
CORM		Coliform removed from treatment	MPN/DT
CORMT		Accumulative total coliform removed by one treatment unit	MPN
COTSLO		Contangent of side slope angle	
CPACRE	C	Cost per acre of land	$/acre
CPCSTT		Total capital cost of installed equipment	$
CPCUYD	C	Unit cost of excavation	$/cy
CPS	C	Capital cost of pump station for storage	$
CRC		Computational variable for CRF	
CRF		Capital recovery factor	
CSTOR	C	Cost of storage	$
CTOTAL	C	Total cost	$
CUMIN	C	Cumulative inflow since start of simulation	cf
CUMOUT	C	Cumulative outflow since start of simulation	cf
C2CSTT		Total chlorine cost	$/storm
DBOD		Dissolved BOD	lb
DDEPTH		Depth increment of storage reservoirs	ft
DEEP		Depth of air flotation tank	ft
DEPMAX	C	Maximum allowable depth in reservoir	ft
DEPTH	C	Water depth	ft
DEPTHL		Depth for previous time-step	ft
DEPTH2		Depth of storage unit	ft
DESF	C	Design flow fraction of maximum flow	
DETENT	C	Detention time	sec
DETMIN		Detention time	min
DS		Suspended solids removed in the filter	lb/DT
DSTART	C	Reservoir depth at start of pumping	ft
DSTOP	C	Reservoir depth at end of pumping	ft
DSTP		Depth at which pumps start up	ft
DSTRT		Depth at which pumps start up	ft
DS1		Suspended solids stored in the filter	lb/DT
DT	C	Time-step interval	min, sec
DTMORE	C	Additional time-step required to pump wet well down	
DTON	C	Number of time-steps pumping occurred	
DTPUMP	C	Dummy variable	
DT2		Half time-step interval	min
DUM		Increment of arriving flow rate	
DUMDEP	C	Storage depth	ft
DUMSTR	C	Storage capacity	cf
DUMTRM		Routing parameter (= ATERM)	cf
DUMAO2		Term in Routing parameter (= $0_2\Delta t/2$)	cf

Table 5-3 (continued)

Variable Name	C*	Description	Unit
DVR		Parameter indicating unreliable storage unit	
ENR		ENR cost index for year and location	
F		Fraction of chemical dosing flow rate to total flow rate of treatment unit	
FACTOR		Integer for unit conversion	
FAREAB	C	Face area of bar screens	sq ft
FMS		Factor for microstrainer	
FON		Fraction of time-step pumped	
FRAC	C	Fraction of an inflow plug	
FRONT		Computational variable for plug flow	
FR2ST		Fraction of totals entering storage unit	
GPMSF		Flow rate through microstrainer	gpm/ft^2
H		Head over weir	ft
H		Head loss through filter (HIGH)	ft
HCL		Head loss thru filter due to solids load	ft
HEAD1	C	Pump head for inlet lift station	ft
HEAD2	C	Pump head for outlet lift station	ft
HIGHRF		Name of subroutine	
HM	C	Maximum design head loss	
HO		Operation head loss through sand of filters	ft
HRFD	C	Multiplier for number of backwash iterations for high rate filters	
H1		Head over weir	ft
I		Bookkeeping integer	
IA		Bookkeeping integer	
ICHEM	C	Indicator noting if chemicals are added	
ICHEMH	C	Indicator noting if chemicals are added to the high rate filter(s)	
ICL2	C	Indicator for chlorine addition	
ICOST	C	Indicator for cost compilation and summary	
IENR		ENR Index	
INTERP		Name of subroutine	
IPOL	C	Pollution control parameter	
IPRINT	C	Print control parameter	
IRANGE	C	Parameter indicating if quantity ranges are summarized	
ISPRIN	C	Print control parameter	
ISTBUP		Indicator of back up effect	
ISTEXS		Indicator for excess flow handling	
ISTINF		Indicator for nonmodel inflow devices	
ISTMOD	C	Indicator for storage mode	
ISTOR	C	Indicator for separate storage modeling	
ISTOUT	C	Indicator for outlet type	
ISTTYP	C	Indicator for type storage structure	
ITABLE	C	Indicator parameter for summarizing inflows and outflows in table form	
ITR		Indicator of illegal combination of treatment	
ITREAT	C	Treatment parameter	
ITR100		ITREAT x 100	

Table 5-3 (continued)

Variable Name	C*	Description	Unit
J		Title parameter	
JM	C	Same as J	
JN	C	Outfall element numbers transferred by file	
JN5	C	Print control counter	
JP	C	Number of first inlet plugs in outflow	
JS	C	Outfall array pointer designating JNS Element	
J1		Variable indicating if bar racks are used, level 1	
J2		Variable indicating if pumping is used, level 2	
J3		Type of primary treatment, level 3	
J4		Type of secondary treatment, level 4	
J5		Variable indicating if there are effluent screens, level 5	
J6		Variable indicating if there is an effluent pump station, level 6	
J7		Variable indicating if there are chlorine contact tanks, level 7	
K		Bookeeping integer for level of treatment	
KDT	C	Time-step number	
KDTBW		Backwash time-step number	
KENR		Number of years from 1969 to the desired year of the ENR cost index	
KFLAG		Interpolation warning flag	
KHOUR	C	Hour of day during simulation	hr

Variable Name	C*	Description	Unit
KILL		Name of subroutine	
KK		Do loop counter	
KMIN	C	Minute during simulation	min
KMOD	C	Bookkeeping integer for module size	
KNCOMB		Number of illegal treatment combinations	
KNECON		Parameter indicating inadvisable treatment combinations	
KNTOF	C	Number of times there is storage overflow	
KP		Inlet plug number	
KPASS		Parameter indicating design flow too large	
KRUN		Do loop variable denoting run number	
KYEAR		Calendar year	
L	C	Do loop counter for level of treatment	
LABEL	C	A label number	
LP	C	Number of last inlet plug in outflot	
LPREV	C	LP for previous time-step	
LR		Variable which indicates type and level of treatment	
M		Do loop counter	
MHOUR		Selected hour of simulation when contaminants removals are computed	
MM		Do loop counter	
MMIN		Selected minute of simulation when contaminants removals are computed	
MMM		Do loop counter	

Table 5-3 (continued)

Variable Name	C*	Description	Unit
MODCST	C	Cost of module	$
MODSIZ	C	Treatment module size	mgd
MODYR		Year of desired ENR	
N		Do loop counter	
NAME	C	Name of the treatment option	
ND		Time-step computation variable	
NDT	C	Number of time-steps	
NDTBW		Number of time-steps for backwash	
NEVEN		Number of high rate filter units in even numbers	
NFLAG	C	Indicator of inadmissible treatment combination or time-step length	
NM	C	Time-step when pollution reduction calculations will be made	
NMS	C	Number of microstrainer units	
NN		Counter for plug flow	
NNCOMB		Number of illegal combinations	
NNECON		Number of inadvisable combinations	
NOCOMB		An illegal combination pair	
NOE		Number of elements	
NOESUN		Number of effluent screens	
NOUNIT		Number of treatment module unit	
NOUTS		Number of outfalls from transport Black	
NPOLL	C	Number of pollutants	
NRUNS		Number of different treatment runs	

Variable Name	C*	Description	Unit
NSCRN	C	Number of screens	
NSED	C	Number of sedimentation tanks used	
NSTIN		Input file number	
NSTOUT		Output file number	
NUE		Number of the upstream element	
NUNITC		Number of dosing units	
NUNITH	C	Number of high rate filter units	
NYEAR		Dummy variable	
NYRS		Amortization periods	years
OFACT		Fraction of overflow rate to total inflow	
OPRA		Operating flow rate of high rate filter	gpm/sq ft
OPRAMA	C	Maximum operating rate for high rate filter	gpm/sq ft
OTCSTT		Total miscellaneous cost for the storm	$/storm
OTHCST		Storm costs excluding chemical cost	$/storm
OTHSC		Non-chemical storm costs for fine screens	$/storm
OVFRA		Overflow rate	gpd/sq ft
OVRDAF	C	Design overflow rate	gpd/sq ft
OVRSED	C	Design overflow rate of sedimentation tank	gpd/sq ft
PBDOF		Pounds of BOD overflowing out of microstrainer	lb
PBDTR		Pounds of BOD treated by microstrainer	lb
PCL2DM		Chlorine demand rate	lb/day

Table 5-3 (continued)

Variable Name	C*	Description	Unit
PCL2MX		Chlorinator capacity required	lb/day
PLUGS		Name of subroutine	
POLL	C	Pollutants	
PSSOF		Pounds of SS overflowing out of microstrainer	lb
PSSTR		Pounds of SS treated by microstrainer	lb
PUMPDV		Volume pumped per time-step	cf
Q		Water flowrate	mgd
QAV		Average flow rate of inflow and outflow $\left(\frac{QQIF + QQRL}{2}\right)$	cfs
QDESYN	C	Design through flow rate for treatment package	cfs
QDSMGD		Design through flow rate for treatment package	mgd
QIN	C	Water inflow rate (hydrograph)	cfs
QINSTL	C	Inflow rate to storage for previous time-step	cfs
QKILL		Disinfectant dosage flow rate	cfs
QMOD	C	Design capacity for treatment module	mgd
QO	C	Outfall flows from TRANS	cfs
QOMAX	C	Maximum outflow from storage unit	cfs
QOUS		Effluent flow rate from screens	cfs
QOUST	C	Outflow rate from storage unit	cfs
QOUSTL	C	Outflow rate for previous time-step	cfs
QOUT		Outflow rate from storage unit	cfs
QOUTO	C	Initial outflow rate	cfs
QPUMP	C	Constant pump at outflow rate	cfs
QQARR	C	Arrival flow rate	cfs
QQESUN		Module capacity of effluent screens	mgd/unit
QQIF	C	Water arrival rate to model	cfs
QQIFT		Total inflow rate to whole model	cfs
QQIFMN		Minimum inflow rate	cfs
QQIFMX	C	Maximum arrival rate of flow from TRANS	cfs
QQIN	C	Inflow rate of one treatment unit	cfs
QQINMN		Minimum inflow rate for a treatment unit	cfs
QQINMX		Maximum inflow rate for a treatment unit	cfs
QQINT		Total inflow rate to one unit	cfs
QQOF		Overflow rate	cfs
QQOFMN		Minimum overflow rate	cfs
QQOFMX		Maximum overflow rate	cfs
QQOFR		Amount of overflow from storage unit	cfs
QQOFT		Total overflow rate	cfs
QQOU	C	Outflow rate	cfs
QQOUMN	C	Minimum outflow rate	cfs
QQOUMX	C	Maximum outflow rate	cfs
QQOUS		Effluent flow rate from screens	cfs

Table 5-3 (continued)

Variable Name	C*	Description	Unit
QQOUT	C	Accumulative total outflow rate for arithmetic average	cfs
QQRL	C	Effluent from treatment plus bypass flow rate	cfs
QQRLMN		Minimum flow rate from treatment units and bypass line	cfs
QQRLMX		Maximum flow rate released from treatment and bypass line	cf
QQRLT		Accumulative flow rate from treatment units and bypass line	cfs
QQRM	C	Removal flow rate	cfs
QQRMMN	C	Minimum removal flow rate	cfs
QQRMT	C	Accumulative removal flow rate by one treatment step	cfs
QQRS		Flow removed by screens	cfs
QRAT		Ratio of design flow to max. flow from from storage unit	
QU		Capacity of high rate filter per unit	mgd
RATEPC		Interest rate for amortization	%
RIJP		Time-step number	
RIL		Time-step	
RILP		Time-step number	
RECIRC	C	Recirculation flow	%
RKTSTP		Number of time-step (= KDT)	
RL		Number time-steps minus one	

Variable Name	C*	Description	Unit
S	C	SS held in high rate filters	lb/sq ft
SBOD	C	BOD in storage unit	lb
SBODC		Average BOD concentration in the storage unit	mg/L
SCIF		SS concentration of the influent	mg/L
SCIFMN		Minimum SS concentration in the influent	mg/L
SCIFMX		Maximum SS concentraton of the influent	mg/L
SCIFT		Accumulative total or arithmetic average of SS concentration of the influent	mg/L
SCIN	C	SS concentration of the inflow to one treatment unit	mg/L
SCINMN		Minimum SS concentration of the inflow	mg/L
SCINMX		Maximum SS concentration of the inflow	mg/L
SCINT		Accumulative total for arithmetic average of SS concentration of the inflow to one treatment level	mg/L
SCOF		SS concentration in the overflow	mg/L
SCOFMN		Minimum SS concentration in the overflow	mg/L
SCOFMX		Maximum SS concentration of overflow	mg/L
SCOFT		Accumulative total for arithmetic average of SS concentration of overflow	mg/L
SCOL	C	Coliform in storage unit	MPN
SCOLC		Coliform concentration in storage unit	MPN/100 ml
SCOU	C	Outflow SS concentration	mg/L
SCOUMN	C	Minimum SS concentration of the outflow	mg/L

Table 5-3 (continued)

Variable Name	C*	Description	Unit
SSOFT		Accumulative total SS in the outflow from the whole model	lb
SSOU	C	SS outflow rate	lb/DT
SSOUS		SS outflow rate from screens	lb/DT
SSOUT	C	Accumulative total SS outflow from one treatment level	lb
SSRD		SS reduction, percentage	%
SSRL	C	SS released per time-step	lb/DT
SSRLT		Total SS released to the whole model	lb
SSRM	C	SS removed per time-step	lb/DT
SSRMT	C	Accumulative total SS removed from each unit	lb
SSRMTT		Total SS removal from the whole model	lb
SSRS		SS removed by screens	lb/DT
SSRST		Accumulative total SS removed by screens	lb
SSS	C	SS in the storage unit	lb
SSSC		Average SS concentration in the storage unit	mg/L
STMTOT		Total storm costs including chemical and others	$
STOR	C	Water in storage	cf
STORAG		Name of subroutine	cf
STORDV		Buffer volume of storage for pumping	
STORHI		Storage volume at pump starting level	cf
STORL	C	Water in storage at previous time-step	cf
STORLO	C	Storage volume at pump stop level	cf
STORMX	C	Maximum storage capacity	cf
STORZ		Water stored per time-step	cf

Variable Name	C*	Description	Unit
STORO	C	Initial storage	cf
STOT		Total volume of outflow plugs	cf
STRAGE		Name of subroutine	
STRDAT		Name of subroutine	
SUAREA	C	Submerged area	sq ft
SUM		Sum of the inflow volume	cf
SUSIN	C	SS inflow rate (pollutograph)	lb/DT
SUSOUT	C	SS outflow	lb/DT
S1		SS held in high rate filters	lb/sq ft
TCHEM		Total chemical used	lb
TERM		Term in routing equation, $S_2 + O_2\frac{\Delta t}{2}$	cf
TIME		Time of time-step	sec
TIME2M		Time since start of inflow	min
TITLE		Title on input file	
TOTCST	C	Dummy variable	
TRCHEK		Name of subroutine	
TRCOST		Name of subroutine	
TREAT		Name of subroutine	
TRIBA	C	Total area of basin	acres
TRLINK		Name of subroutine	
TRTDAT		Name of subroutine	
TSSOUT		Total output of SS	

Table 5-3 (continued)

Variable Name	C*	Description	Unit
TSURFA	C	Total surface area	sq ft
TZERO		Time of start of storm	sec
UAREAH	C	High rate filter area per unit	sq ft
UCCL2		Unit cost of chlorine	$/lb
UCLAND		Unit cost of land	$/acre
UCLIME		Unit cost of alum	$/lb
UCPOLY		Unit cost of polymers	$/lb
UCPOWR		Unit cost of power	$/KWH
UNESN		Design flow/100	cfs/100
UNESNO		Design flow for effluent screens	cfs
VIKK		Inflow volume per time-step (= VOLIN)	cf
VOKK		Outflow volume per time-step (= VOLOUT)	cf
VOLCON	C	Volume of contact tank	cf
VOLDAF	C	Volume of dissolved air flotation tank	cf
VOLIN	C	Inflow water volume per time-step	cf
VOLOUT	C	Outflow water volume per time-step	cf
VOLOUZ		Water outflow per time-step	cf
VOLSED	C	Volume of sedimentation tank	cf
WAIF		Total water inflow per time-step	cf/DT
WAIFRF		Fraction of water removed to water inflow of the whole model	
WAIFT		Accumulative total inflow volume to the whole model	cf
WAIN	C	Water inflow to one treatment level	cf/DT
WAINRF		Fraction of water removed to water flowing into each treatment level	
WAINT	C	Accumulative total inflow volume to one treatment level	cf
WAOF		Volume of overflow per time-step	cf/DT
WAOFT		Total outflow volume from the whole model	cf
WAOU	C	Water volume from one treatment unit	cf/DT
WAOUT	C	Accumulative total water flowing out one treatment level	cf
WARL		Volume of water released per time-step	cf
WARLT		Total water released	ct
WARM	C	Water removed	cf
WARMT	C	Total water removed by one treatment level	cf
WARS		Water removed by fine screens	cf/DT
WARST		Total water removed by screen	cf
WARMTT	C	Total volume of water removed from the whole model	cf
WEIRHT		Reservoir depth when surface at weir elevation	ft
WEIRL		Weir length	ft
WEIRQ		Outflow through fixed weir by gravity	cfs/ft
Y		Data array number	
YE		Output value	
X		Data array number	
XE		Input value	

Table 5-3 (continued)

Variable Name	C*	Description	Unit
SCOUMX	C	Maximum concentration of SS of outflow	mg/L
SCOUS		SS concentration in the outflow from screens	mg/L
SCOUT	C	Accumulative total for arithmetic average of SS concentration in outflow of one treatment level	mg/L
SCRCAP	C	Capacity per screen	cfs
SCREEN	C	Area of fine screen	sq ft
SCRL		SS concentration of the released flow per time-step	mg/L
SCRLMN		Minimum SS concentration of the released flow	mg/L
SCRLMX		Maximum SS concentration in the released flow	mg/L
SCRLT		Accumulative total for arithmetic average of SS concentration of the released flow	mg/L
SCRM	C	SS concentration of the waste flow from a treatment unit	mg/L
SCRMMN	C	Minimum SS concentration in removal flow	mg/L
SCRMMX	C	Maximum SS concentration removal flow	mg/L
SCRMT	C	Accumulative total for arithmetic average of SS concentration of the removal flow by one treatment level	mg/L
SCRM1		SS removed by microstrainer	mg/L
SEDA	C	Surface area of sedimentation tank	sq ft
SEDEP		Sedimentation tank depth	ft
SEDIM		Name of subroutine	
SEDNUM		Number of sedimentation tanks required	
SITEF		An ENR factor for geographic location of site	

Variable Name	C*	Description	Unit
SLOAD		Solids loading on screens	lb/min/sq ft
SOUT		Volume out of plug flow	cf
SPRINT		Name of subroutine	
SQM	C	Maximum solids holding capacity at maximum head and maximum flow rate	lb/sq ft
SREFF		SS removal efficiency	
SREFFH	C	SS removal efficiency of high rate filter	
SREFF1		Same as SREFFH	
SREFF2		Same as SREFFH	
SROUTE		Name of subroutine	
SSARR	C	SS arrival rate	lb/DT
SSCIF		SS concentration of inflow to the whole model (= SSIF)	mg/L
SSCOUT		SS outflow concentration	mg/L
SSCRL		SS concentration of released flow (= SSRL)	
SSIF	C	SS inflow rate (storage)	lb/DT
SSIFRF		Fraction of SS removed to SS flowing into the whole model	
SSIFT		Accumulative total SS in the inflow to the whole model	lb
SSIN	C	SS in flow rate of one treatment level	lb/DT
SSINRF		Fraction of SS removed to SS flowing into each treatment level	
SSINT	C	Accumulative total SS flow into treatment level	lb
SSOF		SS flow rate in overflow	lb/DT

EXAMPLES

Two examples of the use of the Storage Block and its subroutines are given:

Example 1 - Incorporates external storage with bar racks, inlet pumping, sedimentation due to storage, and microstrainers.

Example 2 - Bypasses external storage and provides treatment by bar racks, dissolved air flotation, effluent screens, outlet pumping, and chlorination.

Example 1 - With Storage, Treatment and Cost

This example, as well as the following example, receives most of its data from the Transport Block output file created for a hypothetical 500-acre drainage basin, Smithville. The system outfall is at element 13.

Description of Sample Data. Table 5-4 shows a listing of the card data presented to the program for execution. The first two cards identify the outfall (13), the number of complete runs through the program desired (1), and the desired ratio of the maximum flow to be treated to the maximum arriving flow rate (0.80). This ratio permits a more economical sizing of the treatment units by allowing a fraction of the extreme peak flows to bypass treatment. The third and fourth cards identify the treatment string and print control options. The next nine cards describe the geometry and design parameters of the storage basin. Next follow the inlet pumping head and the clock time of the start of the storm event. The final four data cards describe the cost factors. These four cards are omitted if the no cost option is specified under print control.

Table 5-4. EXAMPLE 1 - CARD INPUT DATA LIST

```
                                                                                  CARD
                                                                                  GROUP
                                   DATA                                           NO.
     13                            TRAN.OUT.SMITHVILLE2 ON SYS04                  1
      1     0.80                                                                  2
02   12   22   35   42   51   61   71                                             3
      2         1         1         1                                             4
 1    1    6                                                                      6
      1         1                                                                 7
  10.71         0                                                                 8
   0.00        0.      2.00   200000.      5.00   400000.      7.50   544000.   )
   8.00   544000.      8.50   544000.      9.00   544000.      9.50   544000.   }  9
  10.00   544000.     10.50   544000.     11.00   544000.                       )
193.250     5.000     0.000      FOR SELBY ST. (*4)                               13
   0.00      0.00                                                                 14
   6.00                                                                           15
  15.00                                                                           16
13   30                                                                           21
   7.00        25      1970    1.1452                                             22
   1314      1346      1378      1410      1442      1474      1506      1538   }  23
   1570      1602      1634                                                     }
 20000.   0.02000      0.20      1.25      0.03                                   24
```

If more than one trial run is to be made from the same transport output file in a continuous operation, the data cards are repeated starting with the Treatment Options.

Description of Sample Output. The output for Example 1 is shown, somewhat abbreviated, in Tables 5-5 through 5-11 inclusive.

Table 5-5 shows the control information read from the Transport Block output file.

Table 5-6 shows the input data and design computations accomplished in subroutines TRTDAT and STRDAT. Note that the storage unit and all treatment units are fully described.

Table 5-7 shows the performance in each level for each time-step. Note that the performance of the storage and treatment units is interwoven in the printed output. The printed output shown here is suppressed by setting IPRINT = 0. In the example the setting IPRINT = 2 was selected to print both quantity and quality performance on a time-step basis. Table 5-7 has been abbreviated to show output only for the first five time-steps.

Table 5-8 shows a summary of the treatment performance at each level and at representative time periods (all levels combined). This summary is suppressed by setting ITABLE = 0.

Table 5-9 shows maximum, average, and minimum values of quantity and quality, at each level. This computation is suppressed by setting IRANGE = 0.

Table 5-5. EXAMPLE 1 - CONTROL INFORMATION PASSED FROM TRANSPORT BLOCK

```
**********
**********
SOLUTION TO EXAMPLE 1 FOR STORAGE BLOCK FOLLOWS
**********
**********
     SMITHVILLE, USA
OUTPUT FROM EXTERNAL STORAGE/TREATMENT MODELS
                TRANSPORT MODEL OUTFALLS AT THE FOLLOWING ELEMENT NUMBERS:
                      13
                INPUT TO TREATMENT MODEL SUPPLIED FROM TRANSPORT MODEL EXTERNAL ELEMENT NUMBER 13

NUMBER OF RUNS              =        1
TIME-STEP SIZE              =     5.00 MIN,
NO. TIME-STEPS MODELED      =       25
TRIBUTARY AREA              =   500.00 ACRES
NO. TRANSP. MOD. OUTFALLS   =        1
NO. OF POLLUTANTS           =        3
TIME ZERO                   =  48600.0 SEC
```

Table 5-6. EXAMPLE 1 - OUTPUT OF SUBROUTINES TRTDAT AND STRDAT

```
------- RUN NO. 1 -------
INPUT DATA FOR TREATMENT PACKAGE FOLLOWS


                CHARACTISTICS OF THE TREATMENT PACKAGE ARE
                     LEVEL     MODE           PROCESS

                       0        02          STORAGE ROUTED
                       1        12            BAR RACKS
                       2        22          INLET PUMPING
                       3        35             STORAGE-SEDIMENTATION
                       4        42          MICROSTRAINERS
                       5        51                               (BYPASS)
                       6        61                               (BYPASS)
                       7        71                               (BYPASS)
                                                                   IPRINT = 2,  ICOST = 1,  IRANGE = 1,   ITABLE = 1


   DESIGN STORM USED.  TREATMENT CAPACITY WILL BE SELECTED TO SUIT.

         DESIGN FLOWRATE =    502.32 CFS.
            (= 0.800 TIMES MAXIMUM ARRIVAL RATE OF    627.89 CFS.)
         TREATMENT SYSTEM INCLUDES MODULE UNITS
            DESIGN FLOW IS THEREFORE INCREASED TO NEXT LARGEST MODULE SIZE
            ADJUSTED DESIGN FLOWRATE =    541.45 CFS., =    350.00 MGD.
            (KMOD = 16)
            CHARACTERISTICS OF STORAGE UNIT ARE
                 OUTLET TYPE  =  6
                 STORAGE MODE =  1
                 STORAGE TYPE =  1
            IPOL = 1, PRINT CONTROL (ISPRIN) = 1
            NATURAL RESERVOIR, WITH MAX. DEPTH =  10.71 FT.          11 DEPTH/AREA PARAMETERS ARE
                 DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)
                    0.00        0.            2.00   200000.            5.00   400000.            7.50   544000.
                    8.00   544000.            8.50   544000.            9.00   544000.            9.50   544000.
                   10.00   544000.           10.50   544000.           11.00   544000.
            RESERVOIR OUTFLOW BY FIXED-RATE PUMPING
            PUMPING RATE = 193.25 CFS, PUMPING START DEPTH =  5.00 FT, PUMPING STOP DEPTH =  0.00 FT
            DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)
               0.00         0.          1.07      57352.         2.14    226873.         3.21    489446.
               4.28    828488.          5.35    1242276.        6.43    1725609.        7.50    2275012.
               8.57   2857542.          9.64    3440165.       10.71    4022788.
            STORAGE BETWEEN PUMP START AND STOP LEVELS =      19.06 TIMES (QPUMP*DT)
            ASSUMED UNIT COST (EXCAVATION, LINING, ETC.) = 6.00 $/CU.YD.
```

Table 5-6 (continued)

```
DESIGN FLOW INPUT TO TREATMENT WILLBE CCNSIDERABLY RESTRICTED BY MAXIMUM POSSIBLE OUTFLOW FROM STORAGE =    193.25 CFS
          THEREFORE REDUCE TREATMENT DESIGN FLOW
SPECIFIED TREATMENT CAPACITY USED.
          DESIGN FLOWRATE =    193.25 CFS.
          TREATMENT SYSTEM INCLUDES MODULE UNITS
               DESIGN FLCW IS THEREFORE INCREASED TO NEXT LARGEST MODULE SIZE
               ACJUSTED DESIGN FLOWRATE =    193.37 CFS., =    125.00 MGD.
               (KMOD = 11)
          PRELIMINARY TREATMENT BY MECHANICALLY CLEANED BAR RACKS  (LEVEL 1)
               NUMBER OF SCREENS   =    2
               CAPACITY PER SCREEN =    96.69 CFS
               SUBMERGED AREA      =    32.23 SQ.FT. (PERPENDICULAR TO THE FLOW)
               FACE AREA OF BARS   =    45.12 SQ.FT.
          INFLCW BY INLET PUMPING (LEVEL 2)
               PUMPED HEAD =  15.00 FT. WATER
          TREATMENT EY SEDIMENTATION IN ASSOCIATED STORAGE - SEE LEVEL 0 ABOVE
               NO CHLORINE ADDED
          TREATMENT BY MICROSTRAINERS
               NUMBER OF UNITS      =         10
               CAPACITY PER UNIT    =      12.50 MGD
               SUBMERGED SCREEN AREA=    217.01 SQ.FT. PER UNIT
          NO EFFLUENT SCREENS  (LEVEL 5)
          OUTFLOW BY GRAVITY (NO PUMPING)  (LEVEL 6)
          NO CHLORINE CONTACT TANK FOR OUTFLOW  (LEVEL 7)
```

Table 5-7. EXAMPLE 1 - OUTPUT OF PERFORMANCE PER TIME-STEP

```
PERFCRPANCE PER TIME STEP
         NOTE:  NO BOD OR SS ARE REMOVED IN LEVELS 2, 5, & 6, REGARDLESS OF THE OPTIONS SELECTED
                NO SS REMOVALS IN LEVEL 7 (CHLORINE CONTACT TANK)
                LEVEL 1 & 5 REMOVALS (AT BAR RACKS AND EFFLUENT SCREENS) ARE REPORTED IN SUMMARY CNLY
 TIME                INFLOWS                      STORAGE           MICROSTRAINERS        NO CONTACT TANK                  OUTFLOWS
               ---------------------------   ------------------  ------------------  ----------------------  ----------------------------
               WATER   BOD    SS COLIFORMS    TOTAL   BOD    SS  TOTAL   BOD     SS  TOTAL    BOD COLIFORPS  TCTAL   BOC     SS COLIFORPS

HR:PIN           CFS  MG/L  MG/L MPN/100ML      CFS  MG/L  MG/L    CFS  MG/L   PG/L    CFS  MG/L MPN/100PL    CFS  MG/L   MG/L MPN/100ML
STORAGE SOLUTICN FCR  25 TIME-STEPS FOLLOWS, ON A STEP-BY-STEP BASIS


U STP TIPE INFLOW OUTFLOW  STORAGE DEPTH  IN: BOD     SS STOR: BOD          SS    BOD      SS OUT: BOD      SS    BOD       SS   J   L
N NO (PIN)  (CFS)  (CFS)   (CU.FT) (FT.)     (LB)   (LB)       (LB)        (LB) (MG/L) (MG/L)     (LB)     (LB) (MG/L) (MG/L)    P   P

   0   0.0    0.0    0.0           0.  0.00

   1   5.0   13.2    0.0       1975.  0.04     44.1   57.7       44.1       57.7  358.1  468.8       0.0     0.0    0.0     0.0   0   0
                                          COLIN=  9.60E 12SCOL(MPN)= 9.60E 12CONC= 1.72E 07COLOUT= 0.00E-01CONC= 0.00E-01

13:35 ARR   0.00     0.     0.  0.00E 00 OUT  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.  0.00E 00  0.00     0.     0.  0.00E 00
      OVF   0.00     0.     0.  0.00E 00 REM  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.
   2  10.0   20.2    0.0       6983.  0.13     46.6   88.0       90.7      145.7  208.4  334.9       0.0     0.0    0.0     0.0   0   0
                                          COLIN=  8.44E 12SCOL(MPN)= 1.80E 13CONC= 9.12E 06COLOUT= 0.00E-01CONC= 0.00E-01

13:40 ARR   0.00     0.     0.  0.00E 00 OUT  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.  0.00E 00  0.00     0.     0.  0.00E 00
      OVF   0.00     0.     0.  0.00E 00 REM  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.
   3  15.0   39.4    0.0      15918.  0.30     66.5  272.3      157.2      417.9  158.5  421.4       0.0     0.0    0.0     0.0   0   0
                                          COLIN=  9.35E 12SCOL(MPN)= 2.74E 13CONC= 6.07E 06COLOUT= 0.00E-01CONC= 0.00E-01

13:45 ARR   0.00     0.     0.  0.00E 00 OUT  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.  0.00E 00  0.00     0.     0.  0.00E 00
      OVF   0.00     0.     0.  0.00E 00 REM  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.
   4  20.0   98.4    0.0      36587.  0.68    138.6 1024.9      255.8     1442.8  129.8  632.9       0.0     0.0    0.0     0.0   0   0
                                          COLIN=  1.62E 13SCOL(MPN)= 4.36E 13CONC= 4.20E 06COLOUT= 0.00E-01CONC= 0.00E-01

13:50 ARR   0.00     0.     0.  0.00E 00 OUT  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.  0.00E 00  0.00     0.     0.  0.00E 00
      OVF   0.00     0.     0.  0.00E 00 REM  -0.00    -0.    -0.  -0.00   -0.    -0.   0.00     0.
                                                                 NEW DSTART =  1.06 FT.
   5  25.0  242.9  193.3      67867.  1.14    295.2 3409.4      407.1     4236.1   96.3 1001.8     184.0   616.2  148.3   496.6   1   4
                                          COLIN=  2.25E 13SCOL(MPN)= 3.55E 13CONC= 1.85E 06COLOUT= 3.05E 13CONC= 5.41E 06
```

Table 5-8. EXAMPLE 1 - OUTPUT OF SUMMARY OF TREATMENT EFFECTIVENESS

```
SUMMARY CF TREATMENT EFFECTIVENESS

                    TOTALS                FLOW (M.G.)     BOD (LB)      SS (LB) COLIF (MPN)
                      INPUT                     9.107       3755.6      53918.5    1.94E 14
                      OVERFLOW (BYPASS)         C.000          0.0          0.0   0.00E-01
                      TREATEC                   9.107       3755.6      53918.5    1.94E 14
                      REMOVED                   0.145       3072.8      51300.4    1.81E 14
                      RELEASED                  8.962        682.8       2618.1    1.34E 13

                    REMOVALS               FLCW(M.G.)     BOD (LB)      SS (LB)
                      LEVEL 1                   0.000         20.5        409.6                        =    BAR RACKS
                      LEVEL 3 (TOTAL)           0.097       1540.8      40561.1                        =     STORAGE
                      LEVEL 4                   0.047       1511.6      10329.6                        =  MICROSTRAINERS
                      LEVEL 5                   0.000          0.C          0.0                        = NO EFFL. SCREENS
                      LEVEL 7                   0.000          0.C          0.0                        = NO CCNTACT TANK
                        TRASH:
                      BAR RACKS                54.617 CU.FT (AT 50 LB/CU.FT.)
                      EFFLUENT SCREENS          0.000 CU.FT (AT 50 LB/CU.FT.)

                    REMOVAL PERCENTAGES    FLCW (VOL)     BOD (LB)      SS (LB) COLIF (MPN)
                      OF OVERALL INPUTS          1.59        81.82        95.14       93.10
                      OF TREATED FRACTIONS       1.59        81.82        95.14       93.10

                    CCNSUMPTICNS (LB)        CHLORINE     POLYMERS
                      LEVEL 3                     0.0          0.0                                     =     STORAGE
                      LEVEL 4                     0.0          0.0                                     =  MICROSTRAINERS
                      LEVEL 7                     0.0          0.0                                     = NO CONTACT TANK
                      TOTAL                       0.0          0.0
                 REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).
           TIME                   13:35     13:45     13:55     14: 5     14:15     14:25     14:35     14:45     14:55     15: 5     15:15
           WATER
             AV. FLOW (CFS)        0.00      0.00    192.57    191.26    191.47    191.49    191.62    191.7C    191.72    191.81    191.86
           BOD
             ARRIVING (MG/L)       0.00      0.00     50.94     76.19     57.92     56.41     48.56     44.15     43.49     39.31     38.18
             RELEASEC (MG/L)       0.00      0.00     10.01     10.01     10.01     10.01     10.01      9.54      9.40      8.48      8.23
             % REDUCTION (LB)      0.00      0.00     80.47     87.12     83.02     82.56     79.71     78.70     78.70     78.71     78.72
           S. SOLIDS
             ARRIVING (MG/L)       0.00      0.00    170.58   1016.35    875.04    859.67    774.06    716.41    707.70    640.95    612.95
             RELEASED (MG/L)       0.00      0.00     35.02     35.02     35.02     35.02     35.02     35.02     35.02     35.02     35.02
             % REDUCTION (LB)      C.00      0.00     79.58     96.62     96.07     95.99     95.55     95.18     95.12     94.61     94.36
           CCLIFCRMS
             ARR (MPN/100ML)  0.COE-01 0.00E-01 1.86E 06 9.82E 05 5.52E 05 5.25E 05 3.97E 05 3.42E 05 3.34E 05 3.00E 05 3.06E 05
             REL (MPN/100ML)  0.0CE-01 0.00E-01 3.81E 05 3.38E 04 2.21E 04 2.14E 04 1.80E 04 1.67E 04 1.65E 04 1.64E 04 1.75E 04
             % REDUCTION (LB)      0.00      0.00     79.64     96.63     96.08     96.01     95.56     95.20     95.14     94.62     94.38
```

Table 5-9. EXAMPLE 1 - OUTPUT OF SUMMARY OF FLOWS--MAXIMUM, AVERAGE, MINIMUM

```
                 SUMMARY OF FLOWS - MAXIMA, AVERAGES, AND MINIMA

                                  TO              LEVEL 3                LEVEL 4                  LEVEL 7        RECOMBINED
             ARRIVING   OVERFLOW  TREATMENT   REMOVAL    OUTFLOW     REMOVAL    OUTFLOW      REMOVAL    OUTFLOW     RELEASE

     FLOW RATES (M.G.D.)
MAXIMUM      124.919      0.000    124.919      1.915    124.688       0.646    124.041        0.000    124.041     124.041
AVERAGE      104.932      0.000    104.932      1.119    103.808       0.543    103.265        0.000    103.265     103.265
MINIMUM        0.000      0.000      0.000      0.226    122.999       0.646    122.352        0.000    122.352       0.000

     BOD CONCENTRATIONS (MG/L)
MAXIMUM         96.9        0.0       96.9     8442.6       57.0      8948.7       10.0          0.0       10.0        10.0
AVERAGE         41.6        0.0       41.6     1793.5       24.5      3228.2        7.7          0.0        7.7         7.7
MINIMUM          0.0        0.0        0.0     1690.6       18.2      2200.3        6.7          0.0        6.7         0.0

     SUSPENDED SOLIDS CONCENTRATIONS (MG/L)
MAXIMUM       1016.4        0.0     1016.4    50043.4      245.5     40093.1       35.0          0.0       35.0        35.0
AVERAGE        597.1        0.0      597.1    42036.4      144.7     22060.7       29.4          0.0       29.4        29.4
MINIMUM          0.0        0.0        0.0    50043.4       74.5      7655.3       35.0          0.0       35.0         0.0

     COLIFORM CONCENTRATIONS (MPN/100ML)
MAXIMUM     1.90E 06  0.00E-01   1.90E 06                                                              3.81E 05    3.81E 05
AVERAGE     4.74E 05  0.00E-01   4.74E 05                                                              3.31E 04    3.31E 04
MINIMUM     0.00E-01  0.00E 00   0.00E-01                                                              0.00E-01    0.00E-01
```

Table 5-10. EXAMPLE 1 - RECAPITULATION OF INPUT/OUTPUT FILES

```
                                          INLET HYDROGRAPH - CFS
EXTERNAL
ELEMENT    TIME STEP
NUMEER         1         2         3         4         5         6         7         8         9        10
  13       13.169    20.214    39.356    98.439   242.862   476.904   626.101   627.894   562.552   466.755
          418.C41   343.250   294.684   254.597   220.755   190.898   167.471   149.583   131.278   101.522
           61.555    48.150    41.579    36.801    32.943
                                          INLET POLLUTOGRAPHS
EXTERNAL
ELEMENT    TIME STEP
NUPEER         1         2         3         4         5         6         7         8         9        10
                                     *** BOD IN LB/MIN ***
  13        8.815     9.316    13.304    27.727    59.049    97.965   118.377   113.826    96.760    75.625
           63.151    47.817    36.927    28.678    22.579    18.111    15.007    13.169    12.639    11.611
            8.578     7.804     7.723     7.761     7.802
                                  ** SUSPENDED SOLIDS IN LB/MIN **
  13       11.539    17.597    54.451   204.980   681.877  1352.822  1794.913  1814.338  1574.737  1233.144
         1013.715   743.326   545.212   392.469   278.744   196.088   138.443    99.772    75.C81    55.357
           33.243    24.903    20.656    17.777    15.635
                                     *** COLIFORMS IN MPN/MIN ***
  13     1.92E 12  1.65E 12  1.87E 12  3.24E 12  4.49E 12  5.29E 12  5.07E 12  4.23E 12  3.37E 12  2.62E 12
         2.30E 12  1.90E 12  1.66E 12  1.49E 12  1.37E 12  1.28E 12  1.22E 12  1.21E 12  1.25E 12  1.18E 12
         8.75E 11  7.89E 11  7.71E 11  7.66E 11  7.62E 11
                                          TREATED OUTFLOW HYDROGRAPH - CFS
EXTERNAL
ELEMENT    TIME STEP
NUPBER         1         2         3         4         5         6         7         8         9        10
  13        0.000     C.000     C.000     0.000   191.892   189.355   189.279   189.310   189.693   189.706
          189.738   189.989   189.989   189.989   190.158   190.183   190.183   190.338   190.379   190.389
          190.461   190.461   190.683   190.726   190.892
                                          TREATED OUTFLOW PCLLUTOGRAPHS
EXTERNAL
ELEMENT    TIME STEP
NUMBER         1         2         3         4         5         6         7         8         9        10
                                     *** BOD IN LB/MIN ***
  13        0.C00     C.000     C.000     0.000     7.188     7.093     7.090     7.091     7.106     7.106
            7.107     7.117     7.117     7.117     6.795     6.692     6.692     6.182     6.C45     6.023
            5.871     5.871     5.278     5.162     4.808
                                  ** SUSPENDED SOLIDS IN LB/MIN **
  13        0.C00     0.000     0.000     0.000    25.158    24.826    24.816    24.820    24.870    24.872
           24.876    24.905    24.909    24.909    24.931    24.934    24.934    24.954    24.960    24.961
           24.971    24.971    25.000    25.005    25.027
                                     *** COLIFORMS IN MPN/MIN ***
  13     0.C0E-01  0.00E-01  0.C0E-01  0.00E-01  1.24E 12  2.16E 11  1.09E 11  9.68E 10  7.11E 10  7.01E 10
         6.89E 10  5.8CE 10  5.8CE 10  5.80E 10  5.39E 10  5.33E 10  5.33E 10  5.30E 10  5.29E 10  5.33E 10
         5.65E 1C  5.65E 1C  6.25E 10  6.39E 10  7.42E 10
```

Table 5-11. EXAMPLE 1 - OUTPUT OF SUMMARY OF TREATMENT COSTS

```
SUPMARY OF TREATPENT COSTS

          ASSUMED FUTURE ENGINEERING NEWS RECORD INDICES
          CCNSTRUCTION  -  20 CITY AVERAGE
                YEAR     ENR INDEX

                1970        1314
                1971        1346
                1972        1378
                1973        1410
                1974        1442
                1975        1474
                1976        1506
                1977        1539
                1978        1570
                1979        1602
                198C        1634
          COST PARAMETERS . .
               INTEREST RATE          =        7.00 PERCENT
               AMORTIZATION PERIOD  =          20 YEARS
               CAP. RECOVERY FACTOR =     0.0858
               YEAR OF SIMULATION     =       1970
               SITE LOCATION FACTOR =     1.1452
          UNIT COSTS . .
               LAND        =  2CCC0.00  $/ACRE
               PCWER       =     0.020 $/KWH
               CHLORINE =     0.200 $/LB
               PCLYMERS =     1.250 $/LB

               ALUP        =     0.03  $/LB
                                     CAPITAL   COSTS              ANNUAL   COSTS                  STORM  EVENT  COSTS
                          ---------  ------------------    -------------------------------    ------------------------------
      TREATMENT            LEVEL       INSTAL       LAND      INSTAL       LAND    MIN MAINT    CHLORINE       CHEM       OTHER
                          ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------
        BAR RACKS             1       356912.      1506.     30627.       105.      3569.        0.         0.        40.
      INLET PUMPING           2       66C558.       616.     56683.        43.     13211.        0.         0.        22.
         STORAGE              3       199179.    312213.     17C92.     21855.      1992.        0.         0.        46.
      MICROSTRAINERS          4      2862998.     26673.    245676.      1867.     57260.        0.         0.        69.
     NO EFFL. SCREENS         5            C.         0.         0.         0.         0.        0.         0.         0.
     NO OUTLET PUMPS          6            C.         0.         0.         0.         0.        0.         0.         0.
     NO CONTACT TANK          7            0.         0.         0.         0.         0.        0.         0.         0.
                          ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------
                          SUBTOTAL $ 4079647. $  341008. $  350C77. $   23871. $   76032. $       0. $       0. $     177.
                          ---------  ------------------    -------------------------------    ------------------------------
                          TOTAL        $ 4420655.          $ 449980.                            $   177.
                          ---------  ------------------    -------------------------------    ------------------------------
                          TOTAL PER
                          TRIB ACRE   $     8841.            $      900.                        $     0.
                          ---------  ------------------    -------------------------------    ------------------------------

                          TOTAL LAND REQUIREMENT =     17.05 ACRES.
```

Table 5-10 shows the hydrograph and pollutograph values received on the Transport Block output file and the values created on the Treatment model output file.

Table 5-11 shows the complete cost summary for the storage/treatment string selected. Cost computations and this summary are suppressed by setting ICOST = 0.

Interpretation of the results is discussed in the context of real examples in Volume II.

Example 2 - Treatment and Cost, Only

Procedures are identical to Example 1 except as noted below.

Description of Sample Data. Table 5-12 shows the listing of the card data presented to the program for execution. Note that the nine storage and one inlet pumping data cards have been deleted. Cards were inserted to describe the design parameters of the dissolved air flotation unit (card number 6) and the outlet pumping head (card number 7).

Also, in this example the design flow (QDESYN), hence the treatment unit size, was specified independent of the modeled storm. This was accomplished by setting DESF = 0 or blank on card 2 and inserting QDESYN in cfs on card 5. This option is useful when evaluating an existing treatment unit or one which was sized for another storm event.

Description of Sample Output. The output for Example 2 is shown in Tables 5-13 through 5-16 inclusive. Note that because the selected design flow was less than the maximum arrival flow rate, a bypass occurred in time-steps 7 through 9 which significantly reduced the overall treatment performance.

Table 5-12. EXAMPLE 2 - CARD INPUT DATA LIST

DATA												CARD GROUP NO.
	13											1
	1											2
01	12	21	32	41	52	62	71					3
	2		1		1		1					4
500.00												5
1	1		5000.00		15.00		10.00					17
	25.00											20
13	30											21
	7.00		25		1970		1.1452					22
	1314		1346		1378		1410	1442	1474	1506	1538	23
	1570		1602		1634							
	20000.		0.02000		0.20		1.25	0.03				24

Table 5-13. EXAMPLE 2 - OUTPUT OF SUBROUTINE TRTDAT

```
------- RUN NO. 1 -------
INPUT DATA FOR TREATMENT PACKAGE FOLLOWS


                    CHARACTISTICS OF THE TREATMENT PACKAGE ARE
                         LEVEL     MODE          PROCESS

                           0        01        NO SEP. STORAGE
                           1        12           BAR RACKS
                           2        21                            (BYPASS)
                           3        32        DISS AIR FLOAT'N
                           4        41                            (BYPASS)
                           5        52        EFFLUENT SCREENS
                           6        62         OUTLET PUMPING
                           7        71                            (BYPASS)
**** WARNING ****
     THE FOLLOWING CCMBINATIONS OF TREATMENT OPTIONS ARE CONSIDERED ECONOMICALLY INADVISEABLE - SIMULATICN CONTINUES
     ITREAT    WITH    ITREAT

       52      WITH      32
                                                                 IPRINT = 2,  ICOST = 1,  IRANGE = 1,  ITABLE
SPECIFIED TREATMENT CAPACITY USED.
        DESIGN FLOWRATE =    500.00 CFS.
        TREATMENT SYSTEM INCLUDES MODULE UNITS
           DESIGN FLOW IS THEREFORE INCREASED TO NEXT LARGEST MODULE SIZE
           ADJUSTED DESIGN FLOWRATE =    541.45 CFS., =    350.00 MGD.
           (KMOD = 16)
        NO STORAGE FROM A SEPARATE STORAGE MOCEL IS ASSOCIATED WITH THIS TREATMENT MCDEL
        PRELIMINARY TREATMENT BY MECHANICALLY CLEANED BAR RACKS  (LEVEL 1)
            NUMBER OF SCREENS    =      2
            CAPACITY PER SCREEN =    270.72 CFS
            SUBMERGED AREA      =     90.24 SQ.FT. (PERPENDICULAR TO THE FLOW)
            FACE AREA OF BARS   =    126.34 SQ.FT.
        INFLOW BY GRAVITY (NO PUMPING)  (LEVEL 2)
        TREATMENT BY DISSOLVED AIR FLOATATION  (LEVEL 3)
            MODULE SIZE         =     50 MGC
            NUMBER OF UNITS     =      7
            TOTAL DESIGN FLOW = 350.00 MGD, = 541.45 CFS
            DESIGN OVERFLOW RATE =   5000.00 GPD/SF,  (5000 SUGGESTED)
            RECIRCULATION FLOW   =     15.00 PERCENT  (15 SUGGESTED)
            TANK CEPTH           =     10.00 FEET
            TOTAL SURFACE AREA   =  80500.00 SQ.FT.
            CHEMICALS WILL BE ADDED
            CHLORINE WILL BE ADDED
        NO SECONDARY TREATMENT INCLUDED  (LEVEL 4)
        TREATMENT BY EFFLUENT SCREENS (LEVEL 5) (FOR AESTHETIC IMPROVEMENTS)
            MODULE SIZE =     58.30 MGD, (MAX = 64.6 MGD.)
            NO. UNITS    =        6
        CUTFLOW BY OUTLET PUMPING (LEVEL 6)
            PUMPED HEAD =  25.00 FT. WATER
        NO CHLORINE CONTACT TANK FOR OUTFLOW  (LEVEL 7)
```

Table 5-14. EXAMPLE 2 - OUTPUT OF PERFORMANCE PER TIME-STEP

```
PERFORMANCE PER TIME STEP
          NOTE:  NO BOD OR SS ARE REMOVED IN LEVELS 2, 5, & 6, REGARDLESS OF THE OPTIONS SELECTED
                 NO SS REMOVALS IN LEVEL 7 (CHLORINE CONTACT TANK)
                 LEVEL 1 & 5 REMOVALS (AT BAR RACKS AND EFFLUENT SCREENS) ARE REPORTED IN SUMMARY ONLY
 TIME                INFLOWS                DISS AIR FLOAT'N    BYPASS LEVEL 4      NO CONTACT TANK               OUTFLOWS
           ---------------------------     ------------------ ------------------ ---------------------- ------------------
           WATER   BOD    SS COLIFORMS       TOTAL   BOD    SS  TOTAL   BOD    SS  TOTAL   BOD COLIFORMS  TOTAL   BOD    SS
HR:MIN       CFS  MG/L  MG/L MPN/100ML         CFS  MG/L  MG/L    CFS  MG/L  MG/L    CFS  MG/L MPN/100ML    CFS  MG/L  MG/L
13:35 ARR  13.17  179.  234.  0.86E 07 OUT  12.97   73.   42.  12.97   73.   42.  12.97   72.  0.84E 04  12.97   72.   42.
      OVF   0.00    0.    0.  0.00E 00 REM   0.20 7141.12501.   0.00    0.    0.   0.00    0.
13:40 ARR  20.21  123.  233.  0.49E 07 OUT  19.91   50.   42.  19.91   50.   42.  19.91   50.  0.48E 04  19.91   50.   41.
      OVF   0.00    0.    0.  0.00E 00 REM   0.30 4913.12417.   0.00    0.    0.   0.00    0.
13:45 ARR  39.36   90.  370.  0.28E 07 OUT  38.76   37.   67.  38.76   37.   67.  38.76   37.  0.28E 04  38.76   37.   67.
      OVF   0.00    0.    0.  0.00E 00 REM   0.59 3601.19907.   0.00    0.    0.   0.00    0.
13:50 ARR  98.44   75.  557.  0.19E 07 OUT  96.96   30.  101.  96.96   30.  101.  96.96   30.  0.19E 04  96.96   30.  101.
      OVF   0.00    0.    0.  0.00E 00 REM   1.48 2955.30111.   0.00    0.    0.   0.00    0.
13:55 ARR 242.86   65.  751.  0.11E 07 OUT 239.21   26.  136. 239.21   26.  136. 239.21   26.  0.11E 04 239.21   26.  136.
      OVF   0.00    0.    0.  0.00E 00 REM   3.64 2587.40702.   0.00    0.    0.   0.00    0.
14: 0 ARR 476.90   55.  759.  0.65E 06 OUT 469.73   22.  137. 469.73   22.  137. 469.73   22.  0.65E 03 469.73   22.  137.
      OVF   0.00    0.    0.  0.00E 00 REM   7.15 2184.41126.   0.00    0.    0.   0.00    0.
14: 5 ARR 626.10   51.  767.  0.48E 06 OUT 533.30   21.  141. 533.30   21.  141. 533.30   21.  0.47E 03 617.95   25.  226.
      OVF  84.65   51.  767.  0.48E 06 REM   8.12 1940.41442.   0.00    0.    0.   0.00    0.
14:10 ARR 627.89   48.  773.  0.40E 06 OUT 533.30   21.  140. 533.30   21.  140. 533.30   21.  0.39E 03 619.75   24.  228.
      OVF  86.44   48.  773.  0.40E 06 REM   8.12 1857.41871.   0.00    0.    0.   0.00    0.
14:15 ARR 562.55   46.  749.  0.35E 06 OUT 533.30   20.  142. 533.30   20.  142. 533.30   20.  0.35E 03 554.41   21.  165.
      OVF  21.10   46.  749.  0.35E 06 REM   8.12 1757.40177.   0.00    0.    0.   0.00    0.
14:20 ARR 466.75   43.  707.  0.33E 06 OUT 459.73   17.  128. 459.73   17.  128. 459.73   17.  0.33E 03 459.73   17.  128.
      OVF   0.00    0.    0.  0.00E 00 REM   7.00 1720.38282.   0.00    0.    0.   0.00    0.
14:25 ARR 418.04   40.  649.  0.32E 06 OUT 411.75   16.  117. 411.75   16.  117. 411.75   16.  0.32E 03 411.75   16.  117.
      OVF   0.00    0.    0.  0.00E 00 REM   6.27 1603.35113.   0.00    0.    0.   0.00    0.

14:30 ARR 343.25   37.  579.  0.33E 06 OUT 338.09   15.  105. 338.09   15.  105. 338.09   15.  0.32E 03 338.09   15.  105.
      OVF   0.00    0.    0.  0.00E 00 REM   5.15 1478.31326.   0.00    0.    0.   0.00    0.
14:35 ARR 294.68   34.  495.  0.33E 06 OUT 290.25   13.   89. 290.25   13.   89. 290.25   13.  0.33E 03 290.25   13.   89.
      OVF   0.00    0.    0.  0.00E 00 REM   4.42 1328.26721.   0.00    0.    0.   0.00    0.
14:40 ARR 254.60   30.  412.  0.34E 06 OUT 250.77   12.   74. 250.77   12.   74. 250.77   12.  0.34E 03 250.77   12.   74.
      OVF   0.00    0.    0.  0.00E 00 REM   3.82 1193.22214.   0.00    0.    0.   0.00    0.
14:45 ARR 220.75   27.  338.  0.37E 06 OUT 217.43   11.   61. 217.43   11.   61. 217.43   11.  0.36E 03 217.43   11.   61.
      OVF   0.00    0.    0.  0.00E 00 REM   3.31 1082.18143.   0.00    0.    0.   0.00    0.
14:50 ARR 190.90   25.  275.  0.40E 06 OUT 188.03   10.   49. 188.03   10.   49. 188.03   10.  0.39E 03 188.03   10.   49.
      OVF   0.00    0.    0.  0.00E 00 REM   2.86 1003.14704.   0.00    0.    0.   0.00    0.
14:55 ARR 167.47   24.  221.  0.43E 06 OUT 164.95   10.   39. 164.95   10.   39. 164.95   10.  0.42E 03 164.95   10.   39.
      OVF   0.00    0.    0.  0.00E 00 REM   2.51  947.11776.   0.00    0.    0.   0.00    0.
15: 0 ARR 149.58   24.  178.  0.49E 06 OUT 147.33    9.   32. 147.33    9.   32. 147.33    9.  0.46E 03 147.33    9.   32.
      OVF   0.00    0.    0.  0.00E 00 REM   2.24  930. 9445.   0.00    0.    0.   0.00    0.
```

Table 5-15. EXAMPLE 2 - OUTPUT OF SUMMARY OF TREATMENT EFFECTIVENESS

```
SUMMARY OF TREATMENT EFFECTIVENESS

              TOTALS                FLOW (M.G.)     BOD (LB)     SS (LB) COLIF (MPN)
                INPUT                    12.717       4650.6     61954.1    2.63E 14
                OVERFLOW (BYPASS)         0.431        176.5      2757.7    6.98E 12
                TREATED                  12.286       4474.1     59196.4    2.56E 14
                REMOVED                   0.185       2664.1     48560.8    2.56E 14
                RELEASED                 12.533       1986.5     13393.2    7.23E 12

              REMOVALS               FLOW(M.G.)     BOD (LB)     SS (LB)
                LEVEL 1                   0.001         27.6       552.6              =     BAR RACKS
                LEVEL 3 (TOTAL)           0.184       2636.2     48003.6              = DISS AIR FLOAT'N
                LEVEL 4                   0.000          0.0         0.0              =  BYPASS LEVEL 4
                LEVEL 5                   0.000          0.2         4.5              = EFFLUENT SCREENS
                LEVEL 7                   0.000          0.0         0.0              = NO CONTACT TANK
                  TRASH:
                BAR RACKS                73.686 CU.FT (AT 50 LB/CU.FT.)
                EFFLUENT SCREENS          0.605 CU.FT (AT 50 LB/CU.FT.)

              REMOVAL PERCENTAGES   FLOW (VOL)      BOD (LB)     SS (LB) COLIF (MPN)
                OF OVERALL INPUTS          1.45        57.29       78.38       97.25
                OF TREATED FRACTIONS       1.50        59.55       82.03       99.90

              CONSUMPTIONS (LB)       CHLORINE      POLYMERS
                LEVEL 3                  1026.1       1228.6                          = DISS AIR FLOAT'N
                LEVEL 4                     0.0          0.0                          =  BYPASS LEVEL 4
                LEVEL 7                     0.0          0.0                          = NO CONTACT TANK
                TOTAL                    1026.1       1228.6
          REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).
      TIME                   13:35      13:45      13:55      14: 5      14:15      14:25      14:35      14:45      14:55      15: 5
      WATER
         AV. FLOW (CFS)      13.07      39.06     241.04     622.03     558.48     414.90     292.47     219.09     166.21     130.29
      BOD
         ARRIVING (MG/L)    179.07      90.43      65.04      50.58      46.01      40.41      33.52      27.36      23.97      25.75
         RELEASED (MG/L)     72.50      36.56      26.26      25.43      20.61      16.27      13.48      10.98       9.61      10.33
         % REDUCTICN (LB)    60.06      60.12      60.17      50.31      55.79      60.27      60.33      60.40      60.46      60.43
      S. SCLICS
         ARRIVING (MG/L)    234.41     370.10     751.05     766.87     748.81     648.66     494.92     337.77     221.13     152.99
         RELEASED (MG/L)     41.74      66.50     136.02     226.40     164.80     117.33      85.28      60.60      39.32      26.89
         % REDUCTICN (LB)    82.43      82.27      82.14      70.82      78.28      82.16      82.21      82.30      82.46      82.66
      CCLIFORMS
         ARR (MPN/100ML)  8.58E 06   2.80E 06   1.09E 06   4.77E 05   3.53E 05   3.24E 05   3.31E C5   3.66E 05   4.30E 05   5.63E 05 8
         REL (MPN/1C0ML)  8.36E 03   2.75E 03   1.08E 03   6.57E 04   1.38E 04   3.20E 02   3.27E C2   3.59E 02   4.18E 02   5.42E C2 8
         % REDUCTION (LB)    99.90      99.90      99.90      86.40      96.15      99.90      99.50      99.90      99.90      99.91
```

Table 5-16. EXAMPLE 2 - OUTPUT OF SUMMARY OF TREATMENT COSTS

```
SUMMARY OF TREATMENT COSTS

          ASSUMED FUTURE ENGINEERING NEWS RECORD INDICES
          CONSTRUCTION  -  20 CITY AVERAGE
                YEAR      ENR INDEX

                1970        1314
                1971        1346
                1972        1378
                1973        1410
                1974        1442
                1975        1474
                1976        1506
                1977        1538
                1978        1570
                1979        1602
                1980        1634
        COST PARAMETERS . .
             INTEREST RATE          =      7.00 PERCENT
             AMORTIZATION PERIOD    =        25 YEARS
             CAP. RECOVERY FACTOR   =    0.0858
             YEAR OF SIMULATION     =      1970
             SITE LOCATION FACTOR   =    1.1452
        UNIT COSTS . .
             LAND      =  20000.00  $/ACRE
             POWER     =     0.020 $/KWH
             CHLORINE  =     0.200 $/LB
             POLYMERS  =     1.250 $/LB
             ALUM      =     0.03  $/LB
                                CAPITAL   COSTS                 ANNUAL   COSTS                    STORM  EVENT  COSTS
                        ---------  ---------------------  ------------------------------  ------------------------------
     TREATMENT            LEVEL     INSTAL       LAND      INSTAL      LAND     MIN MAINT   CHLORINE      CHEM       OTHER
                        ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------
     BAR RACKS              1        941655.     1985.     80804.       139.      9417.        0.         0.         47.
  NO INLET PUMPING          2             0.        0.         0.         0.         0.        0.         0.          0.
  DISS AIR FLOAT'N          3      18306490.    73921.   1570891.      5174.    366130.      205.      1536.         64.
   BYPASS LEVEL 4           4             0.        0.         0.         0.         0.        0.         0.          0.
  EFFLUENT SCREENS          5        714825.     1985.     61340.       139.     10722.        0.         0.         16.
   OUTLET PUMPING           6       1849561.     1269.    158712.        89.     36991.        0.         0.         44.
  NO CONTACT TANK           7             0.        0.         0.         0.         0.        0.         0.          0.
                        ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------
                        SUBTOTAL $21812510. $   79160. $ 1871744. $    5541. $  423260. $     205. $    1536. $     171.
                        ---------  ---------------------  ------------------------------  ------------------------------
                        TOTAL         $ 21891660.                   $ 2300544.                      $    1912.
                        ---------  ---------------------  ------------------------------  ------------------------------
                        TOTAL PER
                        TRIB ACRE     $    43783.                   $    4601.                      $       4.
                        ---------  ---------------------  ------------------------------  ------------------------------
                        TOTAL LAND REQUIREMENT =      3.96 ACRES.
```

SECTION 6

RECEIVING WATER BLOCK

Page

BLOCK DESCRIPTION 293

SUBROUTINE DESCRIPTIONS 294

- Subroutine RECEIV 294
- Subroutine SWFLOW 294
  - Subroutine INDATA 297
  - Subroutine TIDCF 297
  - Subroutine TRIAN 297
  - Subroutine PRTOUT 297
  - Subroutine OUTPUT 301
  - Subroutine SWQUAL 301
  - Subroutine INQUAL 301
  - Subroutine LOOPQL 304
  - Subroutine QPRINT 304

INSTRUCTIONS FOR DATA PREPARATION 304

- Step 1 - Idealization of the Physical System 307
- Step 2 - Quantity Decisions 308
- Step 3 - Quality Decisions 309

EXAMPLE 326

DATA INPUT 326

SECTION 6

RECEIVING WATER BLOCK

BLOCK DESCRIPTION

The Receiving Water Model simulates the behavior of estuaries, reservoirs, lakes, and rivers. The program has two distinct phases which may be simulated together or separately. In Phase A, the time history of stage, velocity, and flow is generated for various points in the system. In Phase B, the hydrodynamics are utilized to model the behavior of conservative and nonconservative quality constituents.

The receiving water is simulated by cutting the continuous system into a series of discrete one- and two-dimensional elements which connect node points. For the purpose of this analysis, the velocity of flow is assumed constant with depth, one-dimensional elements represent rivers and specific channels, and two-dimensional elements represent areas of continuous water surface. For each time-step, the equations of motion and continuity are applied to all nodal points to derive the hydrodynamics of the system. The hydrodynamics are used with equations for conservation of mass to determine the concentration of quality constituents.

Subroutine RECEIV, which is called by the Executive Block program, drives the quantity (Phase A) and quality (Phase B) sections of the model which act independently, linked only by data transmitted through a peripheral file.

This section describes the subroutines used in the Receiving Water Block, provides instructions on data preparation, and furnishes an example of program usage.

Figure 6-1 shows the linkages among subprograms which make up the Receiving Water Block.

SUBROUTINE DESCRIPTIONS

There are three primary subroutines in the Receiving Water Block. Subroutine RECEIV, which provides liaison with the Executive Block of the Storm Water Management program; subroutine SWFLOW, which coordinates the hydraulic computations; and subroutine SWQUAL, which coordinates the quality computations.

Subroutine RECEIV Ⓓ

Subroutine RECEIV reads information to decide if quantity and/or quality are to be simulated and calls SWFLOW and SWQUAL as may be appropriate. The output files generated by either the Transport Block or the Storage Block, as selected by the user when declaring I/O tape/disk identifiers, are used in the computations. Figure 6-2 shows RECEIV flow chart.

Subroutine SWFLOW ①

The quantity model consists of six subroutines: SWFLOW, INDATA, TIDCF, TRIAN, PRTOUT, and OUTPUT.

Subroutine SWFLOW is the driving quantity routine and operates in four steps:

1. Calls INDATA for input.

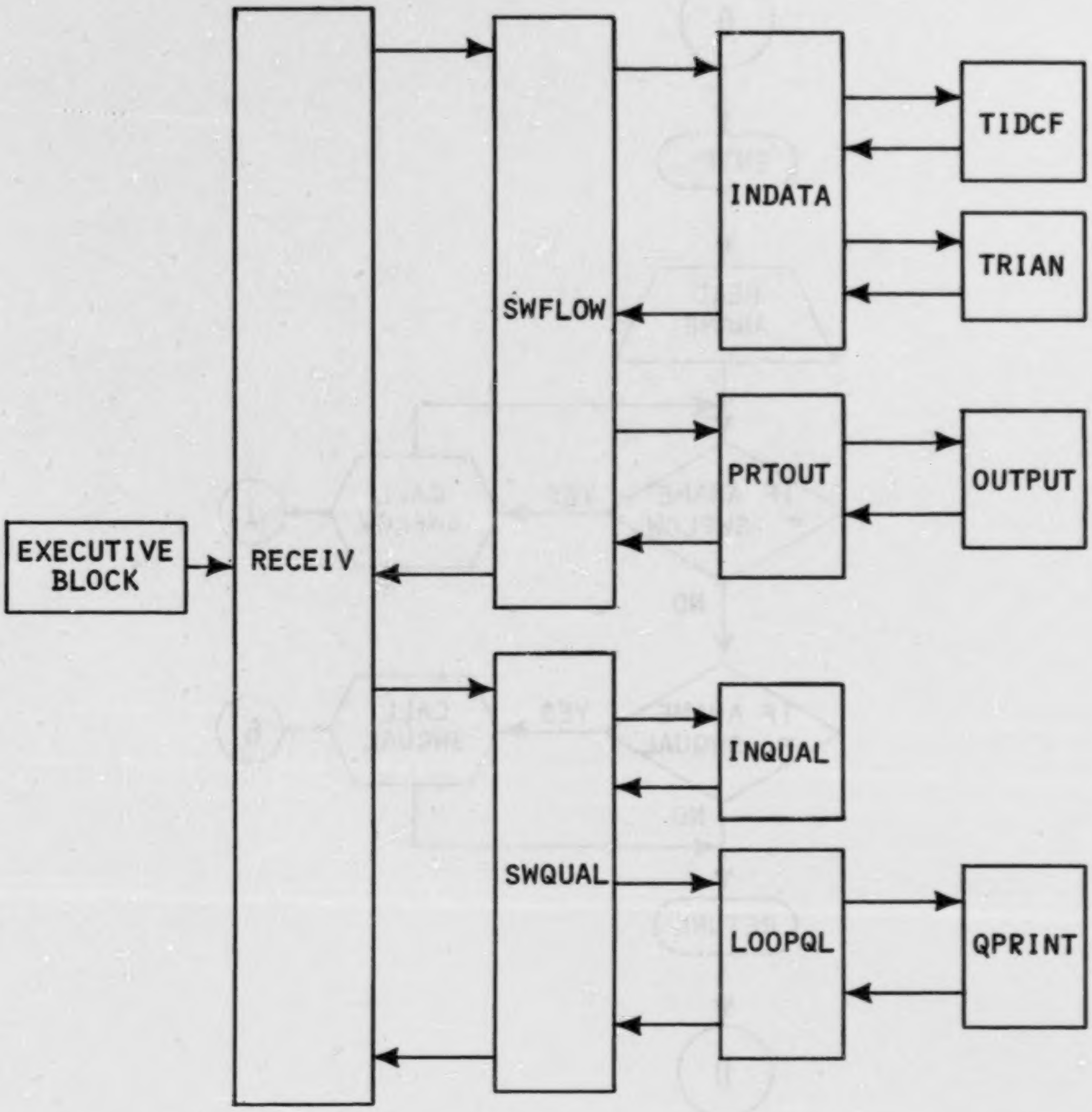

EXECUTIVE BLOCK
RECEIV
SWFLOW
SWQUAL
INDATA
PRTOUT
INQUAL
LOOPQL
TIDCF
TRIAN
OUTPUT
QPRINT

Figure 6-1. RECEIVING WATER BLOCK

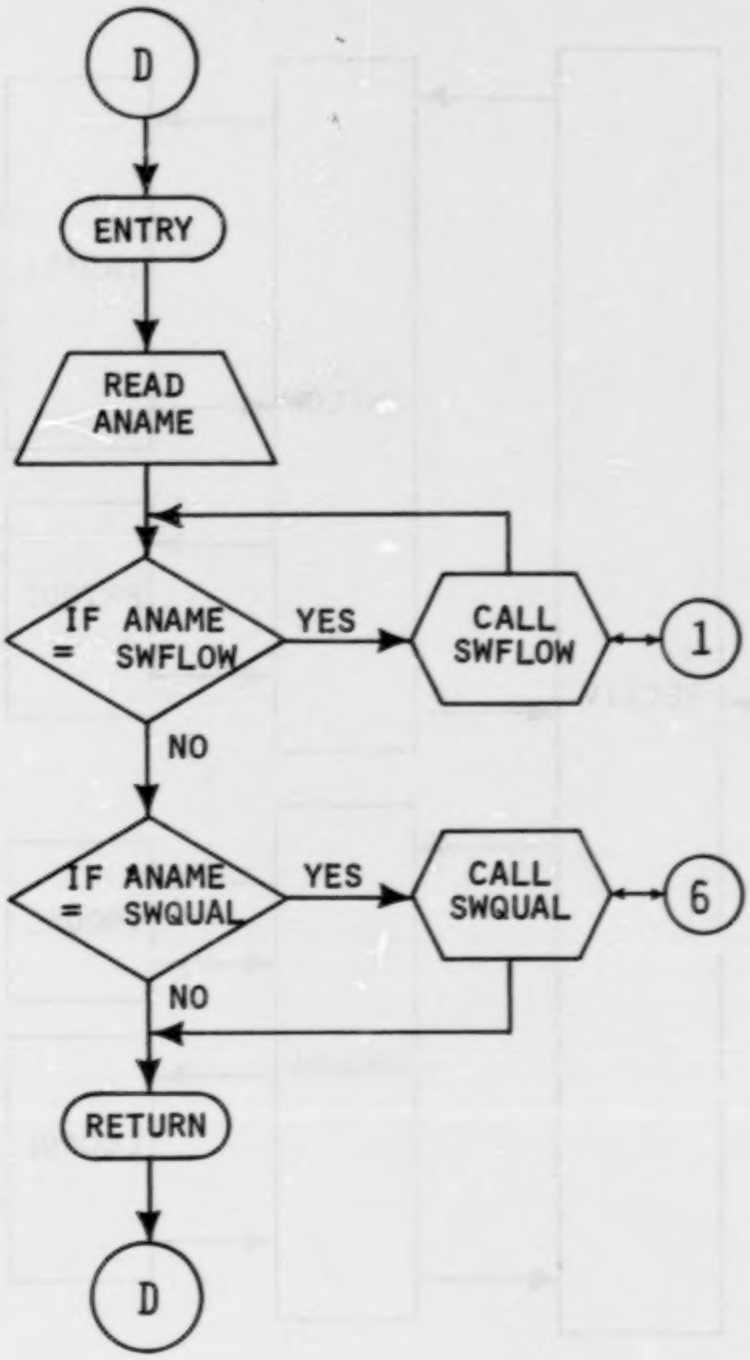

D
ENTRY
READ ANAME
IF ANAME = SWFLOW
YES
CALL SWFLOW
1
NO
IF ANAME = SWQUAL
YES
CALL SWQUAL
6
NO
RETURN
D

Figure 6-2. SUBROUTINE RECEIV

2. Carries out hydraulic computations.
3. Calls PRTOUT for output of results.
4. Saves all geometric and flow information on a peripheral file.

Upon its completion, the program returns with a set of hydrodynamic information required for later calculation of water quality. Figure 6-3 shows a flow chart of subroutine SWFLOW.

Subroutine INDATA. ② Subroutine INDATA reads all the input data for receiving water quality computations. If necessary, it calls TIDCF to generate tidal stage coefficients and TRIAN to calculate necessary geometric data for the system. A flow chart for subroutine INDATA is shown in Figure 6-4.

Subroutine TIDCF. ③ Subroutine TIDCF uses a least square procedure to calculate the coefficients of the tidal function H(T) = A1 + A2 SIN(T) + A3 SIN(2T) + A4 SIN(3T) + A5 COS(T) + A6 COS(2T) + A7 COS(3T) from input values of H and T. A flow chart for subroutine TIDCF is shown in Figure 6-5.

Subroutine TRIAN. ④ Subroutine TRIAN reduces triangular areas to three one-dimensional channel systems with appropriate values for length and width. A flow chart for subroutine TRIAN is shown in Figure 6-6.

Subroutine PRTOUT. ⑤ Subroutine PRTOUT prints the stored information concerning stage, velocity, and flow and then calls subroutine OUTPUT. A flow chart is shown in Figure 6-7.

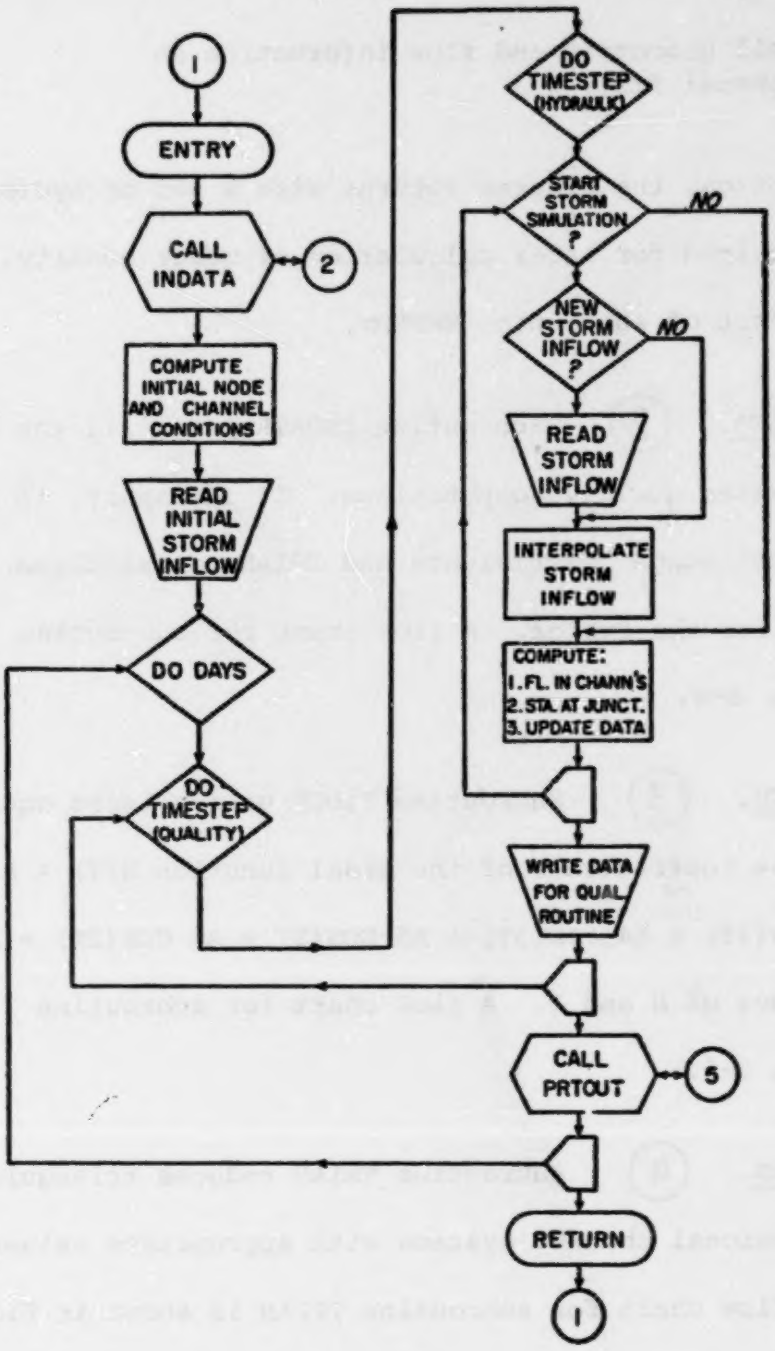

1
ENTRY
CALL INDATA
2
COMPUTE INITIAL NODE AND CHANNEL CONDITIONS
READ INITIAL STORM INFLOW
DO DAYS
DO TIMESTEP (QUALITY)
DO TIMESTEP (HYDRAULIC)
START STORM SIMULATION ?
NO
NEW STORM INFLOW ?
NO
READ STORM INFLOW
INTERPOLATE STORM INFLOW
COMPUTE:
1. FL. IN CHANN'S
2. STA. AT JUNCT.
3. UPDATE DATA
WRITE DATA FOR QUAL ROUTINE
CALL PRTOUT
5
RETURN
1

Figure 6-3. SUBROUTINE SWFLOW

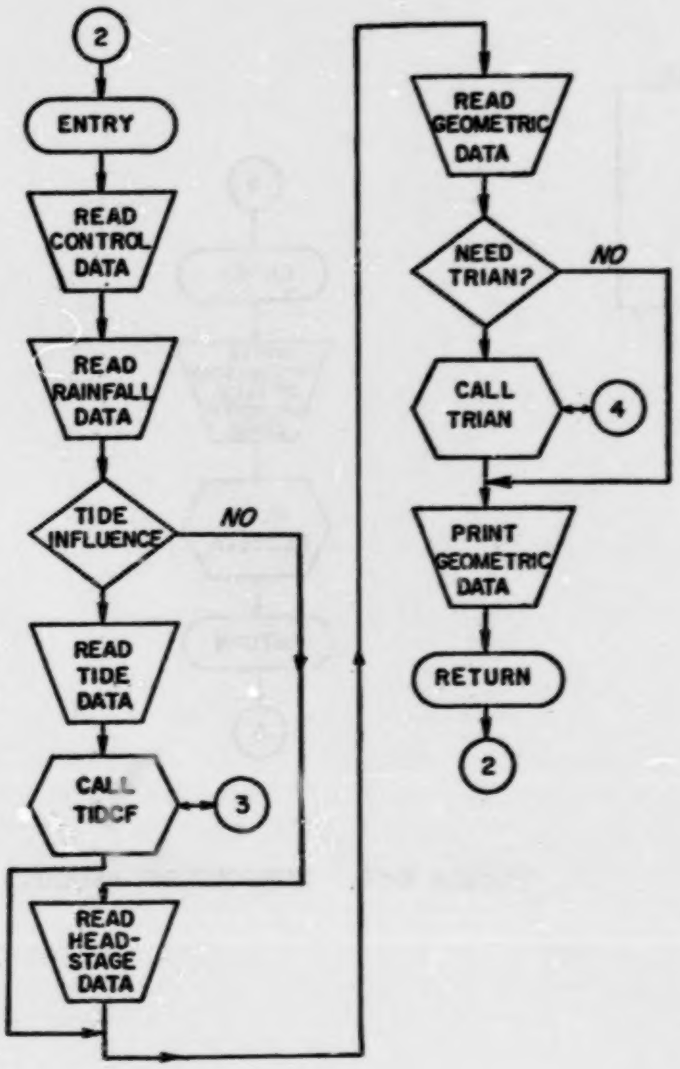

2
ENTRY
READ CONTROL DATA
READ RAINFALL DATA
TIDE INFLUENCE
NO
READ TIDE DATA
CALL TIDCF
3
READ HEAD-STAGE DATA
READ GEOMETRIC DATA
NEED TRIAN?
NO
CALL TRIAN
4
PRINT GEOMETRIC DATA
RETURN
2

Figure 6-4. SUBROUTINE INDATA

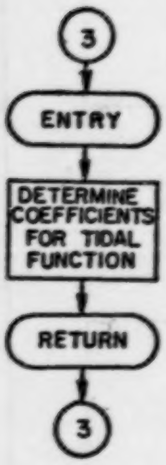

3
ENTRY
DETERMINE COEFFICIENTS FOR TIDAL FUNCTION
RETURN
3

Figure 6-5. SUBROUTINE TIDCF

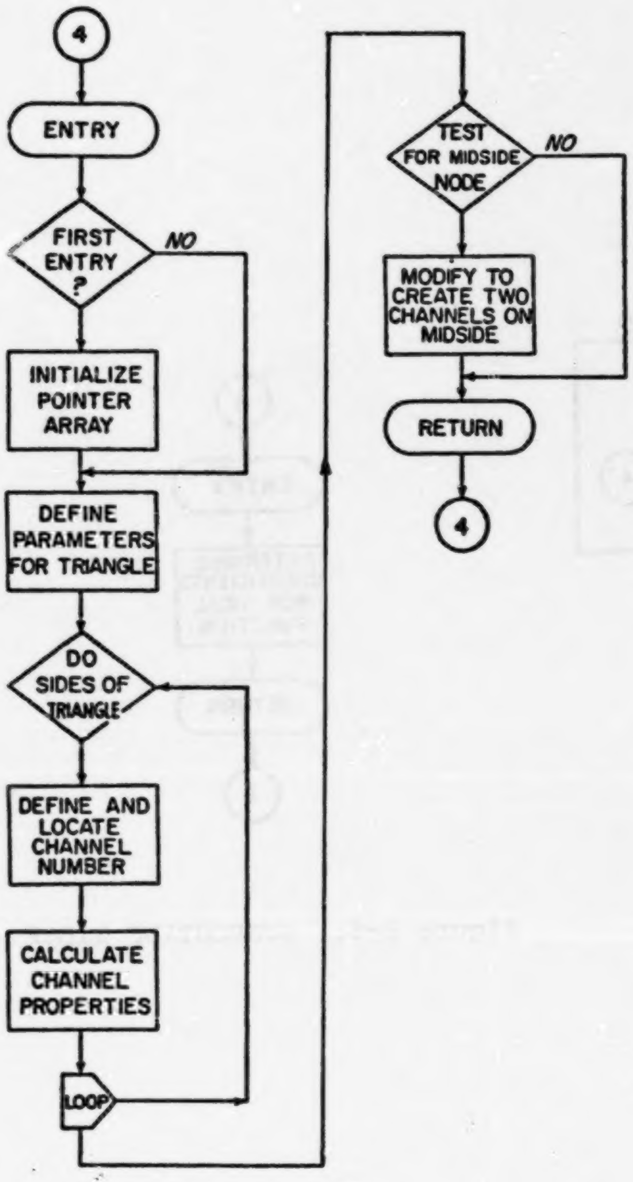

4
ENTRY
FIRST ENTRY ?
NO
INITIALIZE POINTER ARRAY
DEFINE PARAMETERS FOR TRIANGLE
DO SIDES OF TRIANGLE
DEFINE AND LOCATE CHANNEL NUMBER
CALCULATE CHANNEL PROPERTIES
LOOP
TEST FOR MIDSIDE NODE
NO
MODIFY TO CREATE TWO CHANNELS ON MIDSIDE
RETURN
4

Figure 6-6. SUBROUTINE TRAIN

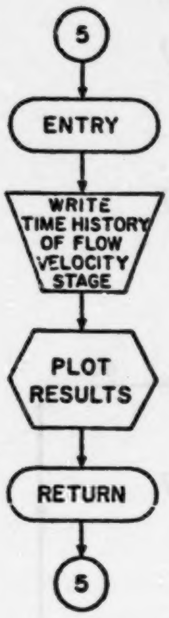

5
ENTRY
WRITE TIME HISTORY OF FLOW VELOCITY STAGE
PLOT RESULTS
RETURN
5

Figure 6-7. SUBROUTINE PRTOUT

Subroutine OUTPUT. Subroutine OUTPUT calls the execution plot routines to draw graphs of the time history of stage.

Subroutine SWQUAL ⑥

The quality section consists of four subroutines: SWQUAL, INQUAL, LOOPQL and QPRINT. Subroutine SWQUAL is the driving quality routine which operates in three steps:

1. Calls INQUAL to read input data.
2. Calls LOOPQL for each day of simulations.
3. Prints daily average, maximum, and minimum concentrations of water quality constituents.

A flow chart of subroutine SWQUAL is shown in Figure 6-8.

Mass lost to the system through outflows is a normal part of the computations. A special case is the mass lost through tidal exchange. This calculation is performed at the completion of each day's cycle, and is based on the volume difference between flood and ebb tides.

Subroutine INQUAL. ⑦ Subroutine INQUAL, shown in Figure 6-9, reads control information from cards and geometric data that was previously the quantity modeling.

The three types and sources of basic information to this subroutine are:

1. The basic hydrodynamics from SWFLOW
2. Time-quality information from models preceding SWFLOW and transferred through it.
3. Initial quality constituent concentrations and controlling parameters.

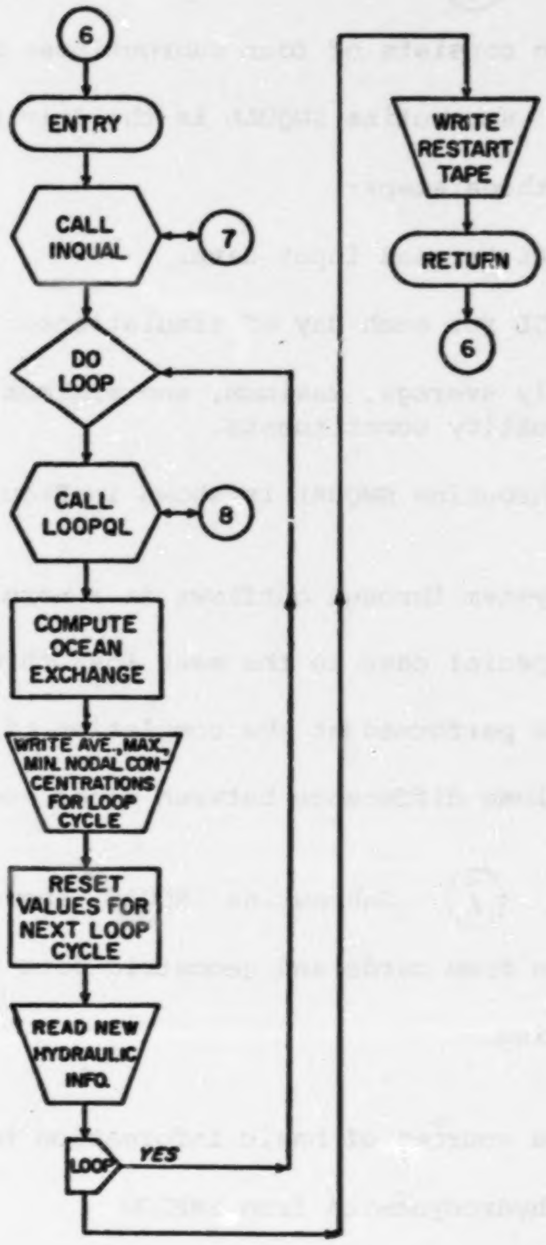

6
ENTRY
CALL INQUAL
7
DO LOOP
CALL LOOPQL
8
COMPUTE OCEAN EXCHANGE
WRITE AVE., MAX., MIN. NODAL CONCENTRATIONS FOR LOOP CYCLE
RESET VALUES FOR NEXT LOOP CYCLE
READ NEW HYDRAULIC INFO.
LOOP?
YES
WRITE RESTART TAPE
RETURN
6

Figure 6-8. SUBROUTINE SWQUAL

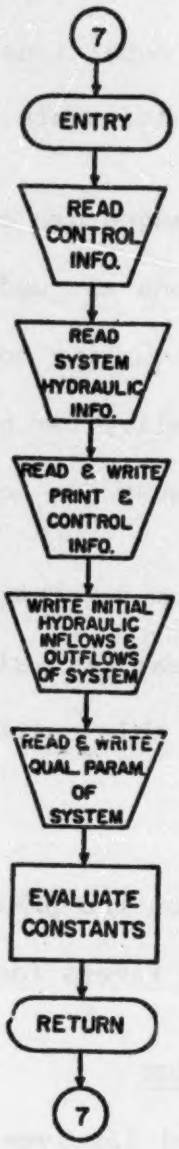

7
ENTRY
READ CONTROL INFO.
READ SYSTEM HYDRAULIC INFO.
READ & WRITE PRINT & CONTROL INFO.
WRITE INITIAL HYDRAULIC INFLOWS & OUTFLOWS OF SYSTEM
READ & WRITE QUAL. PARAM. OF SYSTEM
EVALUATE CONSTANTS
RETURN
7

Figure 6-9. SUBROUTINE INQUAL

Subroutine LOOPQL. ⑧ Subroutine LOOPQL, shown in Figure 6-10, reads one quality cycle of hydraulic information right after its entry. It then reads a new set of values from the appropriate pollutographs or interpolates as necessary. Boundary conditions are computed for conservative and non-conservative quality constituents.

Advective flow concentration changes are computed next, and all nodal quality constituent concentrations are updated, with checks for depletion. The program next computes nodal quality constituent concentration changes due to mass input. Finally, for non-conservative constituents, the effects of reaeration and decay are computed.

The average, maximum, and minimum concentrations are stored for later print out by SWQUAL. This program also allows the calling of QPRINT, to print all concentrations for this quality cycle. Return is made to SWQUAL.

Subroutine QPRINT. ⑨ Subroutine QPRINT, shown in Figure 6-11, prints the instantaneous concentration levels for the system.

INSTRUCTIONS FOR DATA PREPARATION

Use of the Receiving Water Model involves three basic steps:

Step 1 - Idealization of the physical system
Step 2 - Quantity decisions
Step 3 - Quality decisions.

These steps are discussed below. The representation of the data for program input is shown schematically in Figure 6-12. Data card preparation and sequencing instructions for the complete Receiving

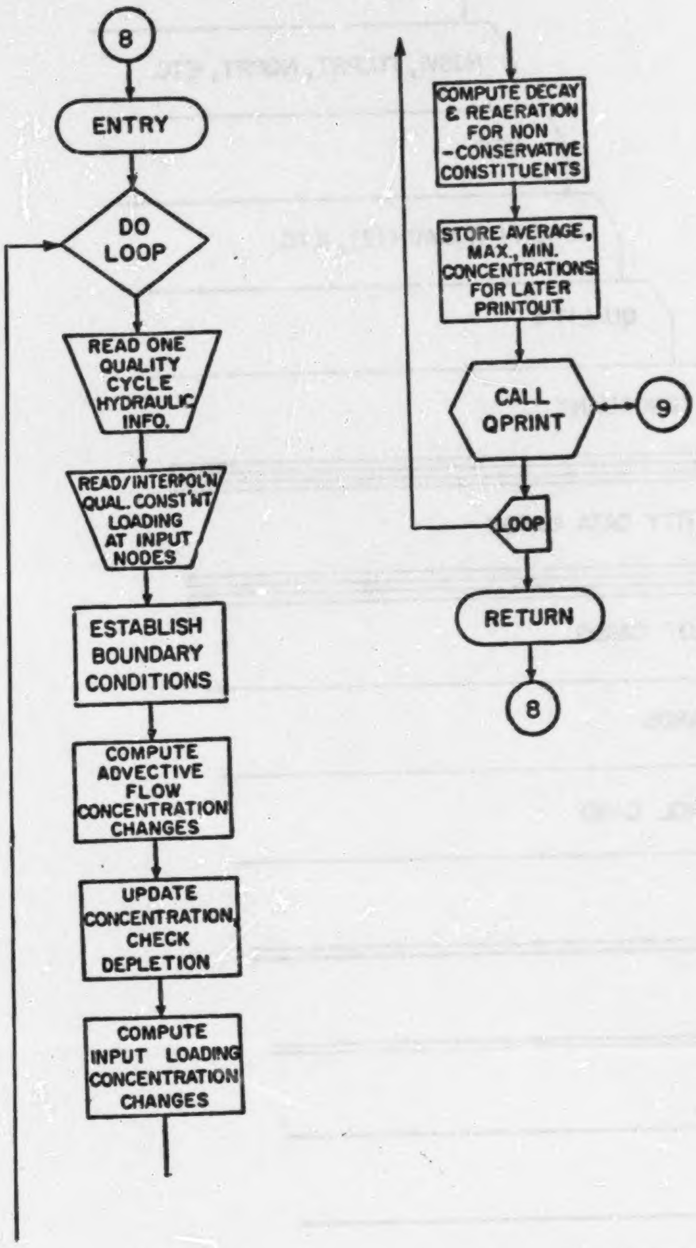

8
ENTRY
DO LOOP
READ ONE QUALITY CYCLE HYDRAULIC INFO.
READ/INTERPOL'N QUAL. CONST'NT LOADING AT INPUT NODES
ESTABLISH BOUNDARY CONDITIONS
COMPUTE ADVECTIVE FLOW CONCENTRATION CHANGES
UPDATE CONCENTRATION, CHECK DEPLETION
COMPUTE INPUT LOADING CONCENTRATION CHANGES
COMPUTE DECAY & REAERATION FOR NON-CONSERVATIVE CONSTITUENTS
STORE AVERAGE, MAX., MIN. CONCENTRATIONS FOR LATER PRINTOUT
CALL QPRINT
9
LOOP
RETURN
8

Figure 6-10. SUBROUTINE LOOPQL

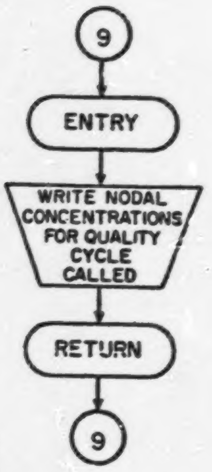

9
ENTRY
WRITE NODAL CONCENTRATIONS FOR QUALITY CYCLE CALLED
RETURN
9

Figure 6-11. SUBROUTINE QPRINT

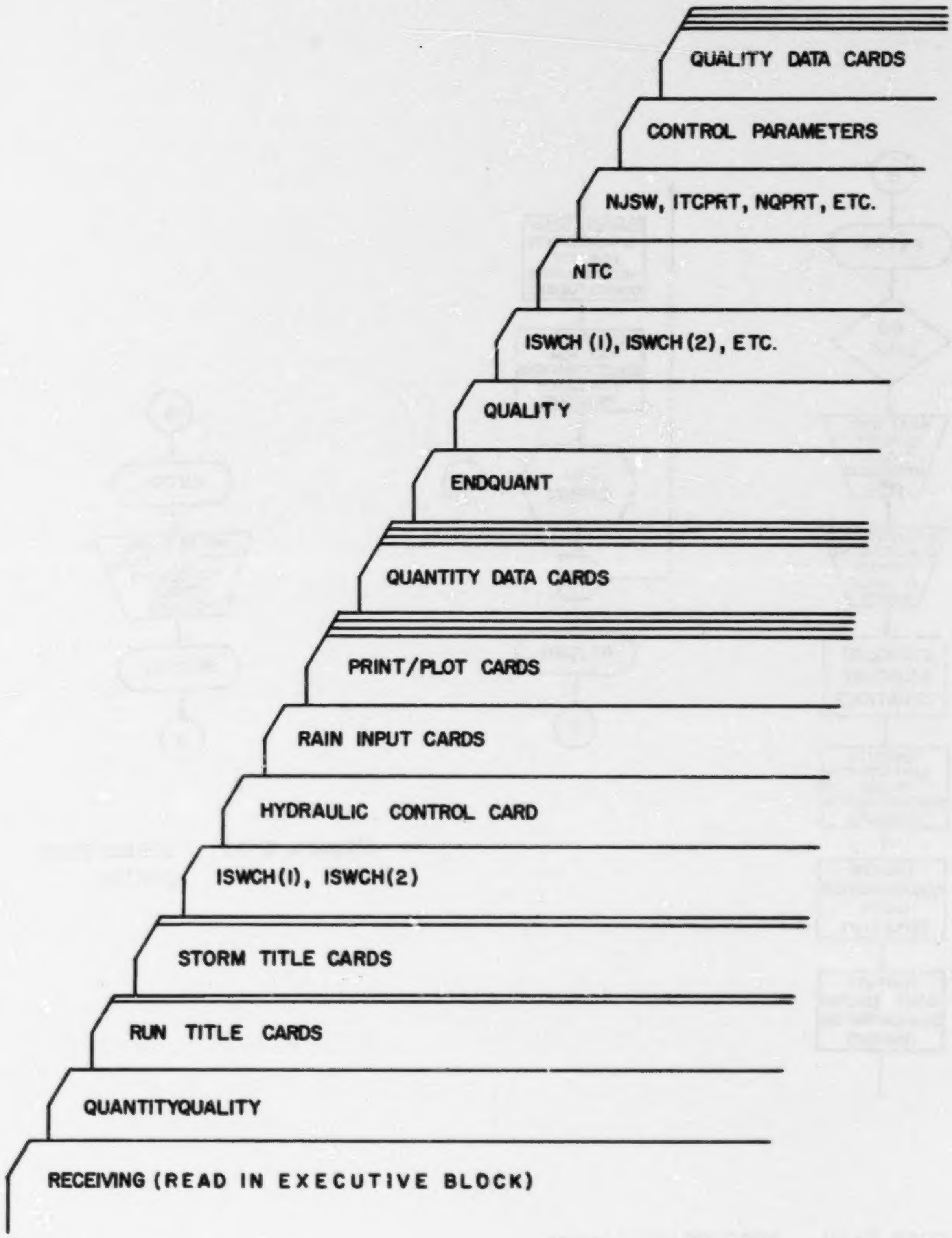

QUALITY DATA CARDS
CONTROL PARAMETERS
NJSW, ITCPRT, NQPRT, ETC.
NTC
ISWCH (I), ISWCH (2), ETC.
QUALITY
ENDQUANT
QUANTITY DATA CARDS
PRINT/PLOT CARDS
RAIN INPUT CARDS
HYDRAULIC CONTROL CARD
ISWCH(I), ISWCH(2)
STORM TITLE CARDS
RUN TITLE CARDS
QUANTITYQUALITY
RECEIVING (READ IN EXECUTIVE BLOCK)

Figure 6-12. DATA DECK FOR RECEIVING WATER BLOCK

Water Block are given at the end of these instructions in Table 6-1, followed by an alphabetical listing of the variable names and descriptions in Table 6-2.

The program uses up to 4 scratch files.

Scratch file 1 is used to transmit hydrodynamics from quantity to quality model.

Scratch file 2 is used as a scratch file by the quantity and quality model separately.

Scratch file 3 is an input restart file for the quality model.

Scratch file 4 is the output restart file for the quality model.

If the restart facilities of the quality model are not used, 3 and 4 need not be defined.

Step 1 - Idealization of the Physical System

The first step in use of the Receiving Water Model is idealization of the physical system into one (channel) and two-dimensional (area) discrete elements of an appropriate size to describe the system in the detail required.

The decision on detail must be based upon the size limitation of the program, and the desired time interval of integration. The time interval is restricted by wave celerity conditions. For a stable solution, choose $\Delta t = 0.75\ L/\sqrt{gd}$ for all channels where L is length, d is depth of channel. Δt will usually lie between 30 seconds and 300 seconds. For junctions of the system, the geometric coordinates, initial head, and floor elevations, plus average friction coefficients must be specified, together with contributions of channels to the surface area of node. For area elements only, the nodes forming triangles must be specified, but for channel elements, width, length, depth, and friction coefficients must be given.

To prepare a run, the following data should be generated. (Card Group designations correspond to the data input instructions, Table 6-1, which follow.)

Step 2 - Quantity Decisions

Card Group	Discussion
1	Quantity and/or quality decision. For a quality run, skip to Card Group 24.
2,3	Title cards for the run and for the storm.
4	Tide or no-tide, print or non-print of input decisions.
5	General control decisions on: (Values in parentheses indicate typical values where relevant.) a) Number of daily cycles. b) Number of hours in a daily cycle (25.). c) Number of hours in a quality cycle (1.). d) Number of seconds in fundamental time-step (180.). e) Zero time (0.). f) Number of junctions and channels to be printed. g) Number of junctions to be plotted. h) Evaporation. i) Wind speed and direction. j) Day cycle at which printed output will start. This is one day before the storm is input allowing steady state to be reached. k) Number of rainfall points if needed. l) Downstream junction number.
6	Rainfall input if relevant.
7,8,9	Junctions and channels to be printed and plotted.
10,11, 12	Downstream condition either tidal or using a weir type equation where Q = WEIR1 (H-WEIR2)**WEIR3.

13,14	Junction data, including initial head, area contribution of one dimensional channels, inflows and outflows, depths, average Manning's coefficient, and coordinates.
15,16	Channel data, including connection data for area elements and connection data for channels plus length, effective width, average depth, Manning's coefficient, and initial velocity.
17,18, 19	Titles to go on plot cards.
20,21, 22	Storm water input hydrograph from cards if relevant.

Step 3 - Quality Decisions

Card Group	Discussion
24	Control switches concerning restart information.
25,26, 27	Control information for quality run information on: a) Number of daily cycles to be run. b) Number of constituents. c) Point frequency and detail required.
28,29, 30	Initial details and junction concentrations for each constituent.
31,32	Storm water input from cards.

BLANK PAGE

Table 6-1. RECEIVING WATER BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1			Control Card.*		
	4A4	1-8	If hydraulic calculations are to be carried out, write QUANTITY.		none
		9-15	If quality modeling is to be accomplished, write QUALITY.		none
			IF QUANTITY ANALYSIS IS NOT SELECTED SKIP TO CARD GROUP 24.		
			QUANTITY MODEL DATA.		
2			Run title card, 2 cards.		
	15A4	1-60	Two card title for run.	ALPHA	none
3			Storm title card, 2 cards.		
	15A4	1-60	Two card title for storm.	TITLE	none
4			Control switches.		
	10I5	1-5	= 1, System is tidally influenced, = 0, System is influenced by downstream head relationship (dam).	ISWCH(1)	0
		6-10	= 0, Print input channel and junction data, = 1, Skip printing of input channel and junction data.	ISWCH(2)	0
5			Hydraulic control card.		
	I5	1-5	Number of day cycles desired.	NTCYC	none
	4F5.0	6-10	Number of hr/day cycle.	PERIOD	none
		11-15	Length of quality time-step, hr.	QINT	none
		16-20	Length of hydraulic time-step, sec.	DELT	none
		21-25	Initial time for start of hydrograph input from cards, hr.	TZERO	none
	3I5	26-30	Number of junctions for time-history printout.	NHPRT	none
		31-35	Number of channels for time-history printout.	NQPRT	none
		36-40	Number of plots desired.	NPLT	0

---

*NOTE: If both QUANTITY and QUALITY are punched, the program first carries out quantity then quality analysis.

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
	3F5.0	41-45	Evaporation, in./mo.	EVAP	0
		46-50	Wind velocity, mph.	WIND	0
		51-55	Wind direction, clockwise, degrees from North.	WDIR	none
	4I5	56-60	Day cycle where printed output will start.	NQSWRT	none
		61-65	Number of junctions of storm water input from cards.	NJSW	none
		66-70	Number of points of rain information.	INRAIN	none
		71-75	Junction number where a head relationship is specified.	JGW	none
			IF INRAIN = 0, SKIP RAIN INPUT CARDS 6 (maximum = 100).		
6			Rain input cards, INRAIN pairs of values, 8 per card.		
	8F10.0	1-10	Rate of precipitation, in./hr.	RAIN(1)	none
		11-20	Time from start of storm, min.	INTIME(1)	none
		21-30	Etc., up to INRAIN points.	RAIN(2)	none
		31-40		INTIME(2)	
7			Junction selected for stage-history printout, NHPRT values, 8 per card (maximum = 50).		
	8I10	1-10	First junction number.	JPRT(1)	none
		11-20	Second junction number.	JPRT(2)	none
		⋮	⋮	⋮	
		⋮	Last junction number.	JPRT(NHPRT)	none
8			Channels selected for flow print, NQPRT values, 8 per card (maximum = 50).		
	8I10	1-7	Lower junction number at end of first desired channel.	CPRT(1)	none
		8-10	Higher junction number at end of first desired channel.		
		11-17	Lower junction number at end of second desired channel.	CPRT(2)	none
		18-20	Higher junction number at end of second desired channel.		
		⋮	⋮	⋮	
		⋮	Lower junction number at end of last desired channel.	CPRT(NQPRT)	none
		⋮	Higher junction number at end of last desired channel.		

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF NPLT = 0, SKIP CARDS 9 (maximum = 50).		
9			Junctions selected for head plot, NPLT values.		
	8I10	1-10	First junction to be plotted.	JPLT(1)	none
		11-20	Second junction to be plotted.	JPLT(2)	none
		⋮	⋮	⋮	
		⋮	Last junction to be plotted.	JPLT(NPLT)	none
			IF ISWCH(1) = 0 ON CARD 4, SKIP TO 12; OTHERWISE INCLUDE CARDS 10 AND 11.		
10			Tide input control card.		
	4I5	1-5	If = 1 will expand from tide points (HHW, LLW, LHW, HLW) for tidal coefficients.	KO	none
		6-10	Number of tidal stage data points.	NI	none
		11-15	Maximum number of iterations for curve fit, usually 50.	MAXIT	none
		16-20	= 0, Skip tidal I/O print, = 1, Print all parameters used.	NCHTID	0
11			Tidal stage card, NI pairs of values, 4 pairs/card.*		
	8F10.0	1-10	Time in hours of tidal stage, first point.	TT(1)	none
		11-20	Tidal stage (ft), first point.	YY(1)	none
		21-30	Time in hours of tidal stage, second point.	TT(2)	none
		31-40	Tidal stage (ft), second point.	YY(2)	none
		⋮	⋮	⋮	
		⋮	Tidal stage (ft), last point.	YY(NI)	none
			SKIP TO 13 IF CARDS 10 AND 11 ARE REQUIRED.		
12			Downstream head stage card.		
	8F10.0	1-10	WEIR factor.	A1	none
		11-20	Elevation of top of WEIR (ft), (referenced to datum plane).**	A2	none
		21-30	Power law for WEIR.	A3	none
			REPEAT CARD 13 FOR EACH JUNCTION (maximum = 100).		
13			Junction cards		
	I5	1-5	Junction number.	J	none
	F5.0	6-10	Water surface-elevation (ft) referenced to datum plane.**	HEAD(J)***	none

---

*Tidal stage is for the first day of simulation.

**Datum plane usually mean low low water.

***Head is negative when below datum plane.

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF NTEMP(3) ON CARD 15 IS SUPPLIED LEAVE SURF BLANK.		
	F10.0	11-20	Surface area of junction (millions of sq ft).*	AS(J)=SURF	none
	2F5.0	21-25	Junction flow into receiving waters (cfs).	QIN(J)=QF1	none
		26-30	Junction flow out of receiving water (cfs).	QOU(J)=QF2	none
	2F10.0	31-40	Junction depth (ft).**	DEP(J)=DT	none
		41-50	Junction Manning's coefficient. (Include Manning's coefficient if program develops geometric data.)	COF(J)=CF	none
	20X	51-70	Leave columns blank.		
	2F5.0	71-75	X-coordinate (thousands of ft).	X(J)=X1	none
		76-80	Y-coordinate (thousands of ft).	Y(J)=Y1	none
14	I5	1-5	To terminate Junction Cards, write 99999.		none
			REPEAT CARD 15 FOR EACH CHANNEL OR AREA (maximum = 225).		
15			Channel or area cards.		
	5I5	1-5	Channel number.	N	none
		6-10	Junction at lower end of channel.	NTEMP(1)	none
		11-15	Junction at upper end of channel.	NTEMP(2)	none
		16-20	Blank unless program is used to develop geometric data. Junction which, with first two junctions, forms an acute triangle. Program will develop channels.	NTEMP(3)	0
		21-25	Blank unless it is a number of a fourth junction which lies between a pair of previous three junctions. Program will develop geometric data.	NTEMP(4)	0
			IF NTEMP(3) IS SUPPLIED THEN LEAVE COLUMNS 26-80 BLANK.		
	5F10.0	26-35	Length of channel (ft).	ALEN	none
		36-45	Width of channel (ft).	WIDTH	none
		46-55	Average depth of channel (ft, referenced to datum plan).	RAD	none
		56-65	Manning's coefficient, n.	COEF	0.018
		66-75	Initial velocity (fps).	VEL	none
16	I5	1-5	To terminate Channel Cards, write 99999.		none

---

*Half of the surface area of the previous channel plus 1/2 of the surface area of succeeding channel.

**Depth is distance to bottom from datum plane (downward is positive).

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF NPLT = 0 (CARD 5), SKIP TO CARD 20.		
17			Plot title card.		
	18A4	1-72	72 Columns title for plot output.	TITL	none
18			Plot horizontal label card.		
	20A4	1-80	80 columns label below the x axis.	HORIZ	none
19			Plot vertical label card.		
	6A4	1-8	Line 1 of the vertical label.	VERT(1) VERT(2)	none
		9-16	Line 2 of the vertical label.	VERT(3) VERT(4)	none
		17-24	Line 3 of the vertical label.	VERT(5) VERT(6)	none
			IF NJSW = 0, SKIP TO CARD GROUP 23 (maximum = 20).		
20			Storm water input control card, NJSW values.		
		1-5	First junction number.	JSW(1)	none
		6-10	Second junction number.	JSW(2)	none
		⋮	⋮	⋮	
			Last junction number.	JSW(NJSW)	none
			REPEAT CARD 21 FOR EACH TIME-STEP (maximum = 20 junctions).		
21			Input hydrograph.		
	8F10.0	1-10	Time of day, sec.	TE(1)	none
		11-20	Flow volume in cfs for first junction.	QE(1,1)	none
		21-30	Flow volume in cfs for second junction.	QE(1,2)	none
		⋮	⋮	⋮	
			Flow volume in cfs for last junction.	QE(1,NJSW)	none
22	F10.0	1-10	Terminate input hydrograph cards with TE(1) beyond expected time of analysis.		none
23			Final data card.		
	2A4	1-8	Write ENDQUANT.		none
			END OF QUANTITY DATA CARDS.		

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			QUALITY MODEL DATA.		
24			Control switches (1 is yes, 0 is no).		
	10I5	1-5	Restart from scratch file 3.	ISWCH(1)	0
		6-10	Skip point of maximum and minimum concentrates.	ISWCH(2)	0
		11-15	Write restart data on scratch file 4.	ISWCH(3)	0
		16-20	BOD/DO is at least one of constituents.	ISWCH(4)	0
		21-25	Tidally influenced receiving water.	ISWCH(5)	0
		46-50	Use only first daily cycle on input file.	ISWCH(10)	0
			IF NOT RESTARTING FROM SCRATCH FILE 3 (i.e., ISWCH(1) = 0), SKIP TO CARD GROUP 26.		
25			Daily cycle card.		
	I5	1-5	Number of daily cycles desired.	NTC	none
			THIS WOULD BE LAST CARD OF DATA DECK IF ISWCH(1) = 0.		
26			Storm water and print card.		
	10I5	1-5	Number of junctions with storm water input from cards (maximum = 20).	NJSW	none
		6-10	Daily cycle at which detailed quality information will print.	JTCPRT	none
		11-15	Number of hours between printing out quality results.	NQPRT	none
		16-20	Total number of quality cycles printed (maximum--50).	LQCPRT	none
27			Control parameters.		
	3I5	1-5	Number of daily cycles desired.	NTC	none
		6-10	Number of constituents.	KCON	none
		11-15	Print interval, days.	NPRT	none
	F5.0	16-20	Ocean exchange ratio at tidal point.	XRQD	none
			FOR EACH QUALITY CONSTITUENT READ A SET OF 28 AND 29 CARDS.		
28			Quality boundary data.		
	I5	1-5	Head-stage control node.	JGW	none
	F10.0	6-15	Concentration at JGW of constituent, mg/L.	CS	none
	3E5.0	16-20	Dissolved oxygen of JGW, mg/L.	CSAT	none

Table 6-1 (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		21-25	Reaeration coefficient, 0.4×10^{-8} is suggested.	REAER	0.4×10^{-8}
		26-30	First order decay exponent for non-conservative constituent.	DECAY	none
	5X				
	6A4	36-55	Constituent name.	TITLE	none
			FOR EACH NODE WITH A NON-ZERO INITIAL VALUE, INCLUDE CARD GROUP 29.		
29			Junction quality data.		
	I5	1-5	Node number.	JTT	none
	4F10.0	6-15	Initial concentration of node.	CTT	none
		16-25	Mass loading, lbs/day.	CPP	none
		26-35	Initial nodal dissolved oxygen concentration.	CTTOX	none
		36-45	Dissolved oxygen concentration of inflow.	CPPOX	none
30	I5	1-5	Terminate card group 29 by writing 99999.		none
			IF NJSW = 1 ON CARD 26 INCLUDE CARD GROUPS 31 AND 32.		
31			Storm water input (16I5) NJSW values (maximum = 20).		
		1-5	First junction for storm water input.	JSW(1)	none
		6-10	Second junction for storm water input.	JSW(2)	none
		⋮	⋮	⋮	
			Last junction for storm water input.	JSW(NJSW)	none
			CARD GROUP 32 MUST BE READ IN GROUPS, EACH GROUP CONSISTING OF KCON NUMBER OF CARDS.		
32			Time and Load Rate (Repeated sets of cards, each set consisting of KCON time groups).		
		1-10	Time of day, sec.	TE	none
		11-20	Load rate of constituent for JSW(1), lbs/day.	CE(1)	none
		21-30	Load rate of constituent for JSW(2).	CE(2)	none
		⋮	⋮	⋮	
			Load rate of constituent for JSW(KCON), lbs/day.	CE(KCON)	none

BLANK PAGE

Table 6-2. RECEIVING WATER BLOCK VARIABLES

Variable Name	C*	Description	Unit
A(I) **	C	Channel cross-section area at start of time-step	sq ft
AA(10)	C	Tidal curve fit coefficients during least square process	
AK(I)	C	Modified friction factor	
ALPHA (30)	C	Title for printing	
ALEN		Channel length	
ANAME		Input variable use for branching to either Quantity or Quality Block	
AREA		Computed nodal area to find initial nodal volume	
AS(J)	C	Node surface area	sq ft
AT(I)	C	Channel cross-section at midpoint of time-step	
		WEIR1 = Weir coefficient	
		WEIR2 = Elevation of weir crest	ft
		WEIR3 = Exponent in the expression $Q = WEIR1(H-WEIR2)^{WEIR3}$ where H is the water surface elevation and Q is the flow.	
ASTERK		Variable containing asterisk	
ATOT		Total surface area of receiving water	sq ft
AX(100,50)	C	Array containing X coordinates of plots	
AY(100,50)	C	Array containing Y coordinates of plots	
A1 A2 A3 A4 A5 A6 A7	C	Coefficients of the expression $H = A1 + A2COS(WT) + A3COS(2WT) + A4COS(3WT) + A5SIN(WT) + A6SIN(2WT) + A7SIN(3WT)$ for tidal input	
B(I)	C	Channel width	ft
BLANK		Variable containing blank	
C(J,6)	C	Constituent nodal concentrations	J=1,NJ K-1,KCON
CARD		Variable for reading second half of final card	
CE(6,20,2)	C	Storm water node input values of loading rate	lb/day
CF		Manning's coefficient for junction	
CLOSS		Constituent concentration lost to decay	
CMAX(J,6)	C	Daily maximum constituent concentration	mg/L
CMIN(J,6)	C	Daily minimum constituent concentration	mg/L
COEF		Manning's coefficient for channel	
COF(J)	C	Junction friction factor	
CPP		Steady state load rate for load node JTT	lb/day
CPPOX		Steady state DO inflow concentration	mg/L
CPRT(K)	C	Channel print array	
CS(6)	C	Conservative constituent concentration at controlled state-time node (JGW)	mg/L
CSAT(6)	C	DO constituent concentration at JGW	mg/L
CSPIN(J,6)	C	Initial constituent mass input levels	
CT(6,20,2)	C	Constituent loading rate from storm water input	lb/day
CTT		Initial node JTT constituents concentrations	mg/L
CTTOX		Initial node JTT DO concentrations	mg/L
C2(6)	C	Concentration at controlled stage-time node (JGW)	mg/L

*Variable names shared in common blocks.
**In variable dimensions I is for number of channels, J is for number of junctions, and K is for number of point junctions, channels, and plots.

Table 6-2 (continued)

Variable Name	C	Description	Unit
CURVE		Name of subroutine	
D		Dummy read variable	
DCDT(J,6)	C	Change of nodal concentration with time	
DECAY(6)	C	First order delay coefficient for nonconservative constituents	1/day
DELH		Increment of head of a junction for a time-step	ft
DELMAX		Maximum difference between the calculated and tidal stage input	ft
DELT	C	Time-step increment	
DELTA		Maximum allowable difference between the calculated and input tidal stage	ft
DELTQ	C	Length of quality time-step (usually an hour)	sec
DELT2		1/2 time-step increment	sec
DELV1, DELV2		Component of velocity change during a time-step	ft/sec
DEP(J)	C	Depth of water of a junction at zero datum	ft
DEPTH		Computed depth of node at a junction for initial volume	
DIFF		Difference between the calculated and input tidal stage	ft
DISOXY		Part of label for nonconservative constituents	mg/L
DT		Junction depth	ft
DUMMY		Dummy write variable to indicate end of data	
DVOL		Volume change in a time-step	cf

Variable Name	C*	Description	Unit
EBB		Total flow leaving system at tidal junction	cf
ENDER(2)		Array containing ENDQUANT to terminate model	
EVAP	C	Evaporation rate for whole system converted from ft/mo	cfs
FINAL		Variable for reading first half of final card	
FJ1		Internal variable	
FJ3		Internal variable	
FLOOD		Total flow entering system at tidal junction	cf
FWIND(I)	C	Drag force due to wind	
G		Channel length determined from X & Y coordinates	ft
H(J)	C	Head at junction at beginning of time-step	ft
HAVE(J)	C	Junction average head during a daily cycle	ft
HBAR(J)	C	Junction average head during a quality cycle	ft
HEAD		Distance water surface is from datum plane	ft
HN(J)	C	Junction head at end of time-step	ft
HORIZ	C	Graph horizontal axis title	
HOUR		Time-hours	hr
HPLT(K)	C	Array saved on scratch for later plotting	ft

Table 6-2 (continued)

Variable Name	C*	Description	Unit
HT(J)	C	Junction head at end of 1/2 time-step	ft
IABS		Name of function	
IC		Internal variable	
ICOL	C	Printing column header	
ICON(6)		Bookkeeping integer for nonconservative constituents	
IDELT		Length of hydraulic cycle (integration step)	sec
IDUM	C	Column heading for channel printout	
II		Channel number	
INDATA		Name of subroutine	
INQUAL		Name of subroutine	
INRAIN		Number of rainfall inputs	
INSTM	C	Switch to cause reading of pollutograph from hydrograph file after one daily cycle	
INTIME(100)	C	Time of rainfall inputs	
IPERID		Length of tidal cycle	hrs
IPOINT(J,8)	C	Pointer array containing node to node connections	
IQINT		Length of quality cycle	sec
ISKIP	C	Printing counter	
ISW(20)	C	Storm water input junctions from hydrograph file	
ISWCH(10)	C	Control switches	
ITCPRT	C	Day cycle chosen for start of detailed quality printing	

Variable Name	C*	Description	Unit
JBOUND(20)	C	Junction with specified boundary conditions	
JGW	C	Junction with specified head flow or head relationships	
JH		Highest numbered junction at the end of a channel	
JJ		Lowest numbered junction at the end of the channel	
JJBOUN	C	Number of junctions with specified boundary conditions	
JPLT(K)	C	Array of junctions to be plotted	
JPRT(K)	C	Array of junctions for stage printout	
JSW(20)	C	Storm water input node numbers from cards	
JTT		Node number for special start conditions	
KCON	C	Number of constituents, including DO for nonconservative	
KCONO	C	Number of constituents	
KO		Switch to cause generation of a full tide from HHW, LLW, HLW, LHW	
KPRT	C	Counter for printing, standard output	
KRAIN		Counter for interpolation of rainfall input	
KSTART		Do loop start point for DO loop	
LEN(I)	C	Channel length	ft
LOOPQL		Name of subroutine	
LQCPRT	C	Desired total number of detailed quality print cycles	

Table 6-2 (continued)

Variable Name	C*	Description	Unit
LTIME	C	Printing counter	
MADD(J,6)	C	Mass of nodal constituent	
MAXIT		Maximum number of iterations in tidal curve fit, usually 50	
MCOUNT		Card read counter at end of SWFLOW	
MCPRT		Channel numbers for which flow and velocity are to be printed	
MINO		Name of function	
MJSW		Number of storm water input nodes from hydrograph file	
MJPRT		Junction numbers for which stage is to be printed	
MSTPRT	C	Printing counter for quality cycle, used in QPRINT	
MTOTAL		Printing counter, total hours printed	
NC	C	Number of channels	
NCHAN(J,8)	C	Channels associated with nodes	
NCHTID		Print control for tide generation	
NCLOS(I)	C	If equal to 1 channel dry, otherwise no effect	
NCON		Number of quality constituents on hydrograph input file	
NCURVE		Number of points on plotted curves	
NDC		Total number of curves	
NDRY		Number of dry junctions	
NEBB		Number of cycle with outflow at tide junction	
NEXIT	C	Set equal to 1 when error condition exists	
NFLD		Number of cycles with inflow at tide junction	
NH		Node at channel end	
NHCYC	C	Number of time-steps per quality cycle	
NHPRT	C	Number of junctions at which head will be printed	
NI		Number of tidal input values	
NINREC		Counter for tape storm water input	
NINT		Number of hydraulic cycles per tidal cycle	
NJ	C	Number of junctions	
NJSW	C	Number of storm water input junctions for cards	
NJUNC(I,2)	C	Nodes at channel ends	
NL		Node at channel end	
NPDEL	C	Number of time-steps per plot point	
NPLT	C	Number of points to be plotted	
NPRT	C	Standard output print interval, in days	
NPT	C	Number of parts on card curve	
NPTOT		Counter of time-steps for plotting	
NQ		Quality cycle counter	
NQCTOT	C	Printing counter	
NQCYC	C	Number of quality cycles per day	hr

Table 6-2 (continued)

Variable Name	C*	Description	Unit
NQPRT	C	Quality cycle interval increments between detailed quality cycle prints (SWQUAL)	hr
NQSWRT	C	Number of daily cycles at which printing will start	
NSTEPS		Number of input records on input hydrograph file	
NSTART	C	Day DO loop start cycle	
NSTPRT	C	Printing counter, day cycle	
NT	C	Daily cycle number	
NTAG		Day, DO loop counter	
NTC	C	Number of day cycles	
NTCYC	C	Number of daily cycles to be simulated	
NTEMP(8)	C	Temporary array of channels entering a node	
NTIMS		Number of times through drying up connection	
NTINT	C	20 for first call to output 21 for subsequent calls	
NUMCH(I)	C	Array containing compacted form of junction connections	
NX		Number of curves to be plotted on one plot	
N5	C	Card reader	
N6	C	Printer	
N10	C	Scratch file number	
N20	C	SWFLOW-SWQUAL interfacing file	
N21	C	Input file containing hydrographs	
N22		Scratch file containing plot information	
N30	C	Restart input file	
N40	C	Output file	
OGAIN		Dissolved oxygen gained from reaeration	
PERIOD	C	Period in hours of daily cycle	hr
PREC		Instantaneous rainfall rate	ft/sec
PRTH(30,K)	C	Array for printing heads	ft
PRTOUT		Name of subroutine	
PRTQ(30,K)	C	Array for printing flows	cfs
PRTV(30,K)	C	Array for printing velocities	ft/sec
Q(I)	C	Channel flow	cfs
QAVE(I)	C	Daily cycle average flow	cfs
QBAR(I)	C	Quality cycle average flow	cfs
QE(20,2)	C	Inflows on input cards (subroutine SWFLOW)	cfs
QF	C	Total inflow to system through control node, 1-day cycle	cfs
QIN(J)	C	Inflows to junctions	cfs
QINBAR(J)	C	Quality cycle average junction inflow	cfs
QINST		Initial inflow to junction	cfs
QINT		Quality time-step interval	hr
QOU(J)	C	Outflow from junction	cfs
QOUBAR(J)	C	Quality cycle average junction outflow	cfs
QT(20,2)	C	Inflows from hydrograph input file	cfs
QUIN(J)		Flow into system at nodes	cfs
QUINST(J)		Instantaneous inflow rate	cfs
R(I)	C	Hydraulic radius	ft

Table 6-2 (continued)

Variable Name	C*	Description	Unit
RAD		Channel depth measured from datum	ft
RAIN(100)	C	Rainfall hyetograph values	in/ft
REAER(6)	C	Reaeration coefficient	day/ft^2
RES		Accumulative difference between the calculated and input tidal stage	ft
RNT		Temporary hydraulic radius at 1/2 time-step	ft
SIGN		Library function	
SLOPE	C	Instantaneous rate of change of inflow	ft/sec^2
SUM		Computed tidal stage	ft
SUMC(J,6)		Average daily nodal concentration	
SUMQ		Total flow leaving junction	cfs
SWFLOW		Name of subroutine	
SWQUAL		Name of subroutine	
SXX(10,10)	C	Matrix used for least square tidal fit	
SXY(10)	C	Vector used for least square tidal fit	
T	C	Time counter for whole analysis	sec
TDELT		Time-step of hydrograph input file	sec
TE	C	Time of inflow for card input	sec
TEMP		Simplifying variable used during solution of velocities	
TEO	C	Previous value of TE	sec
TEP	C	Time of inflow in hours	hr
TF		Estimate maximum time-step for channel	sec
TIME		Time counter for storm input	sec

Variable Name	C*	Description	Unit
TITEL2		Input hydrograph title	
TITLE(40)		Title array read from input hydrograph file	
TITLE(30)	C	Title array read from cards	
TITLESW(30)	C	Description of run	
TMAX		Dummy write variable to indicate end of data	
TOLD		Time of previous input rainfall	sec
TT(50)	C	Time from start of storm of input for tidal condition and from hydrograph file	sec
TTP		Times of previous input from hydrograph file	sec
TZ		Time of start of storm	hr
TZERO	C	Zero time for the analysis	sec
T2		Time at end of half hydraulic time-step	sec
U(225)	C	Channel velocity	
V	C	Channel velocity at start of time-step	ft/sec
VBAR	C	Average nodal volume during quality cycle	cf
VOL(J)	C	Nodal volume	cf
VOLO(J)	C	Volume of JGW	
VOLUME		Initial nodal volume	cf
VT	C	Channel velocity at 1/2 time-step	ft/sec
V2		Velocity during a half hydraulic time-step	ft/sec
W		Fundamental frequency of daily tidal variation	rad/sec

Table 6-2 (continued)

Variable Name	C*	Description	Unit
WDIR	C	Wind direction in degrees from north	deg
WEIR1		Weir coefficient	
WEIR2		Elevation of weir crest	ft
WEIR3		Exponent in the expression $Q = WEIR1 (H-WEIR2)^{WEIR3}$ where H is the water surface elevation and Q is the flow	
WIDTH		Width of channel	ft
WIND	C	Wind force	mph
X(J)	C	X coordinate of junctions	ft
XMK		Blank or asterisk depending on whether estimated maximum time-step is satisfied	
XRQD	C	Mass exchange ratio of JGW	
XX(10)	C	Vector used in least square tidal fit	
Y(J)	C	Y coordinate of junctions	ft
YY(50)	C	Stage level of tidal input	ft

EXAMPLE

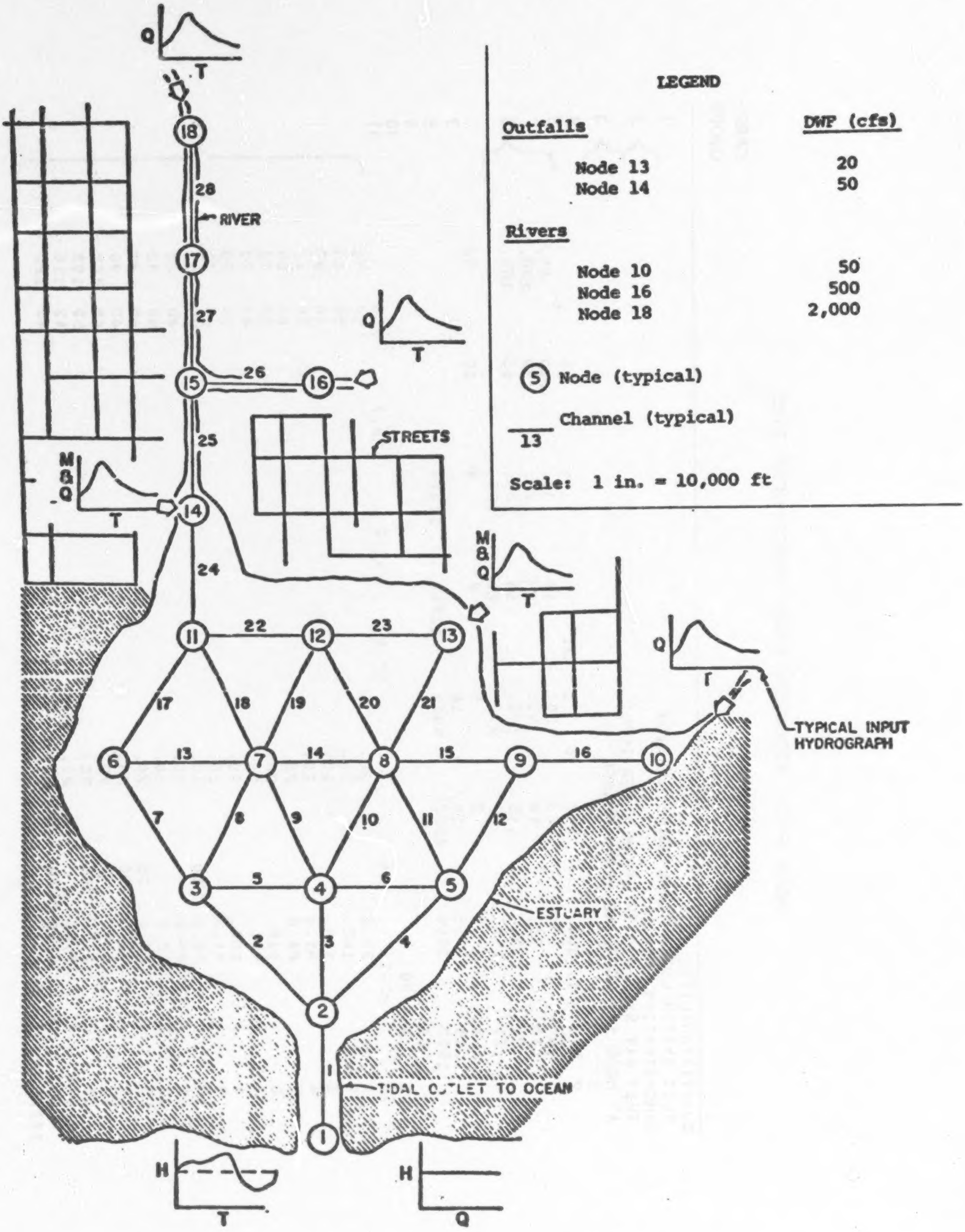
Figure 6-13 shows an example discretized system. The system is an estuary with the main inflow coming at junction 18, and others at junctions 10, 13, 14, and 16. A tidal stage-time relationship is used at junction 1 and storm water input is used at junction 14.

Listed in Table 6-3 are the data input for two daily simulations with the storm entering on the second day. Quantity output for a selected number of junctions and channels is specified in Table 6-4 and sample quality output in Table 6-5. The quality output is for a non-conservative pollutant, and the associated dissolved oxygen levels are included in the sample quality output.

DATA INPUT

The Receiving Water Block requires storm water hydrographs and pollutographs as input. This can be interfaced from the Transport or Storage Block via tape transfer, and/or it can be read from cards. The data must contain identification of storm input nodes, and then must have a sequence of information such that a time, a flow rate for each input node, and/or a mass rate for each input node are defined.

The Receiving Water Block can operate with either interfacing-tape input or card input or a combination of both. This complete flexibility allows, as an example, several quality cases with different card input mass loadings at node A, using the same basic hydraulics and node B interfaced tape pollutograph, all cases run simultaneously.



LEGEND
Outfalls
DWF (cfs)
Node 13 20
Node 14 50
Rivers
Node 10 50
Node 16 500
Node 18 2,000
5 Node (typical)
13 Channel (typical)
Scale: 1 in. = 10,000 ft
Q
T
RIVER
STREETS
M & Q
ESTUARY
TIDAL OUTLET TO OCEAN
TYPICAL INPUT HYDROGRAPH
H
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Figure 6-13. DEMONSTRATION ESTUARY

Table 6-3. RECEIVING WATER BLOCK INPUT DATA

```
                                                                                         CARD
                                                                                         GROUP
QUANTITYQUALITY
 TEST SYSTEM USING FINAL MODEL VERSION                                                   1
DEMONSTRATION DECK
 TEST BAY SYSTEM WITH STORM WATER INPUT                                                  2
 AT NODE 14, MODELING URBAN RUNOFF
    1                                                                                    3
    2  25.   1. 300.        12    6    1   3.              1    0   15    1              4
       .03       15.       .03       30.       .15       45.       .15       60.         5
       .15       75.       .18       90.       .18      105.       .32      120.
       .21      135.       .45      150.       .63      165.       .63      180.
       .21      195.       .21      210.       .21      225.                             6
         1         2         3         5         8         9        10        12
        14        15        16        18
      1002      3004      4007      6011     11012     11014                             7
        14                                                                               8
    1    4   50                                                                          9
   .3      -1.1       5.8      .7        11.6      -2.0       18.7      2.4              10
    1           20.0            20.                                      50   50         11
    2           102.            20.                                      50   60
    3           114.            20.                                      40   60
    4           81.0            20.                                      50   70
    5           86.0            20.                                      60   60
    6           118.            20.                                      35   70
    7           100.            20.                                      45   70
    8           100.            20.                                      55   70
    9           81.0            20.                                      65   70
   10           20.0   50       20.                                      75   70         13
   11           94.0            20.                                      40   80
   12           98.0            20.                                      50   80
   13           67.0   20       20.                                      60   80
   14           5.80   50       20.                                      40   90
   15           6.40            20.                                      40  100
   16           1.5   500       20.                                      50  100
   17           5.00            20.                                      40  110
   18           2.50 2000       20.                                      40  120
77777
```

Table 6-3 (continued)

```
    1   1   2              10000      4000        20       .03        ┐
    2   2   3              14100      8500        20       .01        │
    3   2   4              10000     10000        20       .01        │
    4   2   5              14100      6500        20       .01        │
    5   3   4              10000     11000        20       .01        │
    6   4   5              10000     10000        20       .01        │
    7   3   6              11200     10000        20       .01        │
    8   3   7              11200      9500        20       .01        │
    9   4   7              11200      9500        20       .01        │
   10   4   8              11200      9500        20       .01        ├15
   11   5   8              11200      9500        20       .01        │
   12   5   9              11200      9000        20       .01        │
   13   6   7              10000     10000        20       .01        │
   14   7   8              10000     10000        20       .01        │
   15   8   9              10000     10000        20       .01        │
   16   9  10              10000      7000        20       .03        │
   17   6  11              11200      9000        20       .01        │
   18   7  11              11200      9500        20       .01        │
   19   7  12              11200      9500        20       .01        │
   20   8  12              11200      9500        20       .01        │
   21   8  13              11200      8000        20       .01        │
   22  11  12              10000     10000        20       .03        │
   23  12  13              10000      9500        15       .03        │
   24  11  14              10000       650        17       .03        │
   25  14  15              10000       500        17       .03        │
   26  15  16              10000       300        10       .03        │
   27  15  17              10000       500        15       .03        │
   28  17  18              10000       500        15       .03        ┘
99999
TEST SYSTEM ONLY                                                       17
TIME IN HOURS                                                          18
STAGE IN FEET                                                          19
ENDQUANTITY                                                            23
    o   1   0    1    1                                                25
    0   2   5    5                                                     27
    2   1   1   .2                                                     28
    1     0.0  8.0 .4-8   .2      TEST CASE, BOD-DO                    29
99999                                                                  30
```

Table 6-4. SAMPLE QUANTITY OUTPUT

```
 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


DAYS SIMULATED   2

WATER QUALITY CYCLES PER DAY  25

INTEGRATION CYCLES PER WATER QUALITY CYCLE  12

LENGTH OF INTEGRATION STEP IS  300. SECONDS

INITIAL TIME   .00 HOURS

EVAPORATION RATE,  3.0 INCHES PER MONTH

WIND VELOCITY,   0. MPH   WIND DIRECTION,   0. DEGREES FROM NORTH

SWITCH ONE EQUALS   1

WRITE CYCLE STARTS AT THE   1 TIME CYCLE


RAIN IN INCHES PER HOUR, AND TIME IN MINUTES, MEASURED FROM START OF STORM

             IN./HR.   MINUTES     IN./HR.   MINUTES     IN./HR.   MINUTES     IN./HR.   MINUTES     IN./HR.   MINUTES

  1 TO   5     .030     15.000       .030     30.000       .150     45.000       .150     60.000       .150     75.000
  6 TO  10     .180     90.000       .180    105.000       .320    120.000       .210    135.000       .450    150.000
 11 TO  15     .630    165.000       .630    180.000       .210    195.000       .210    210.000       .210    225.000
 16 TO  20     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 21 TO  25     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 26 TO  30     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 31 TO  35     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 36 TO  40     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 41 TO  45     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 46 TO  50     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 51 TO  55     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 56 TO  60     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 61 TO  65     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 66 TO  70     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 71 TO  75     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 76 TO  80     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 81 TO  85     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 86 TO  90     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 91 TO  95     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 96 TO 100     .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
PRINTED OUTPUT AT THE FOLLOWING 12 JUNCTIONS

          1    2    3    5    8    9   10   12   14   15   16   18

          AND FOR THE FOLLOWING  6 CHANNELS

          1002      3004      4007      6011     11012     11014
```

Table 6-4 (continued)

```
JUNCTION  INITIAL HEAD   SURFACE AREA   INPUT    OUTPUT             CHANNELS ENTERING JUNCTION                COORDINATES
 NUMBER       (FT)      (10**6 SQ FT)   (CFS)     (CFS)                                                          X      Y

    1          .00          20.00         0.        0.        1    0    0    0    0    0    0    0       50.0   50.0
    2          .00         102.00         0.        0.        2    3    4    1    0    0    0    0       50.0   60.0
    3          .00         114.00         0.        0.        5    7    8    2    0    0    0    0       40.0   60.0
    4          .00          81.00         0.        0.        6    9   10    3    5    0    0    0       50.0   70.0
    5          .00          86.00         0.        0.       11   12    4    6    0    0    0    0       60.0   60.0
    6          .00         118.00         0.        0.       13   17    7    0    0    0    0    0       35.0   70.0
    7          .00         100.00         0.        0.       14   18   19    8    9   13    0    0       45.0   70.0
    8          .00         100.00         0.        0.       15   20   21   10   11   14    0    0       55.0   70.0
    9          .00          81.00         0.        0.       16   12   15    0    0    0    0    0       65.0   70.0
   10          .00          20.00        50.        0.       16    0    0    0    0    0    0    0       75.0   70.0
   11          .00          94.00         0.        0.       22   24   17   18    0    0    0    0       40.0   80.0
   12          .00          98.00         0.        0.       23   19   20   22    0    0    0    0       50.0   80.0
   13          .00          67.00        20.        0.       21   23    0    0    0    0    0    0       60.0   80.0
   14          .00           5.80        50.        0.       25   24    0    0    0    0    0    0       40.0   90.0
   15          .00           6.40         0.        0.       26   27   25    0    0    0    0    0       40.0  100.0
   16          .00           1.50       500.        0.       26    0    0    0    0    0    0    0       50.0  100.0
   17          .00           5.00         0.        0.       28   27    0    0    0    0    0    0       40.0  110.0
   18          .00           2.50      2000.        0.       28    0    0    0    0    0    0    0       40.0  120.0
     .110220+10

 TEST BAY SYSTEM WITH STORM WATER INPUT                       AT NODE 14, MODELING URBAN RUNOFF

CHANNEL   LENGTH    WIDTH      AREA    MANNING   VELOCITY   HYD RADIUS          JUNCTIONS AT ENDS   MAX INT
 NUMBER    (FT)      (FT)    (SQ FT)    COEF.      (FPS)       (FT)

    1     10000.    4000.       80.     .030        .00        20.0                 1     2         352.
    2     14100.    8500.      170.     .010        .00        20.0                 2     3         497.
    3     10000.   10000.      200.     .010        .00        20.0                 2     4         352.
    4     14100.    6500.      130.     .010        .00        20.0                 2     5         497.
    5     10000.   11000.      220.     .010        .00        20.0                 3     4         352.
    6     10000.   10000.      200.     .010        .00        20.0                 4     5         352.
    7     11200.   10000.      200.     .010        .00        20.0                 3     6         395.
    8     11200.    9500.      190.     .010        .00        20.0                 3     7         395.
    9     11200.    9500.      190.     .010        .00        20.0                 4     7         395.
   10     11200.    9500.      190.     .010        .00        20.0                 4     8         395.
   11     11200.    9500.      190.     .010        .00        20.0                 5     8         395.
   12     11200.    9000.      180.     .010        .00        20.0                 5     9         395.
   13     10000.   10000.      200.     .010        .00        20.0                 6     7         352.
   14     10000.   10000.      200.     .010        .00        20.0                 7     8         352.
   15     10000.   10000.      200.     .010        .00        20.0                 8     9         352.
   16     10000.    7000.      140.     .030        .00        20.0                 9    10         352.
   17     11200.    9000.      180.     .010        .00        20.0                 6    11         395.
   18     11200.    9500.      190.     .010        .00        20.0                 7    11         395.
   19     11200.    9500.      190.     .010        .00        20.0                 7    12         395.
   20     11200.    9500.      190.     .010        .00        20.0                 8    12         395.
   21     11200.    8000.      160.     .010        .00        20.0                 8    13         395.
   22     10000.   10000.      200.     .030        .00        20.0                11    12         352.
   23     10000.    9500.      142.     .030        .00        15.0                12    13         394.
   24     10000.     650.       11.     .030        .00        17.0                11    14         376.
   25     10000.     500.        8.     .030        .00        17.0                14    15         376.
   26     10000.     300.        3.     .030        .00        10.0                15    16         455.
   27     10000.     500.        8.     .030        .00        15.0                15    17         394.
   28     10000.     500.        8.     .030        .00        15.0                17    18         394.
```

Table 6-4 (continued)

```
 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


 TEST BAY SYSTEM WITH STORM WATER INPUT                    AT NODE 14, MODELING URBAN RUNOFF

DAY IS   2

 * * * * * * * * * * * * * * * * * * * *   T I M E  H I S T O R Y  O F  S T A G E   * * * * * * * * * * * * * * * * * * * *

                    JUNCTION    1    JUNCTION    2    JUNCTION    3    JUNCTION    5    JUNCTION    8    JUNCTION    9
      HOUR           HEAD(FEET)        HEAD(FEET)        HEAD(FEET)        HEAD(FEET)        HEAD(FEET)        HEAD(FEET)

       .00            -1.0724            -.7359            -.8143            -.7789            -.5992            -.7633
      1.00            -1.0488           -1.0920           -1.1506           -1.1398           -1.0692           -1.1416
      2.00             -.7261           -1.0295           -1.0786           -1.0780           -1.0457           -1.0788
      3.00             -.2253            -.5553            -.5695            -.5740            -.5435            -.5561
      4.00              .2840             .3503             .3638             .3508             .4132             .4418
      5.00              .6289             .5911             .5359             .5014             .5852             .6520
      6.00              .6024             .8205             .7559             .7597             .8807             .7583
      7.00              .4009             .7996             .7320             .7358             .9986             .6947
      8.00             -.1605             .3798             .2912             .2540             .6791             .2181
      9.00             -.8605            -.2511            -.3223            -.3538             .0351            -.3629
     10.00            -1.5099            -.9091            -.9515            -.9514            -.7575            -.9620
     11.00            -1.9230           -1.5065           -1.5283           -1.5206           -1.4607           -1.5396
     12.00            -1.9681           -1.9403           -1.9648           -1.9616           -1.9501           -1.9723
     13.00            -1.6023           -1.9665           -2.0177           -2.0177           -2.0242           -2.0299
     14.00             -.8318           -1.5000           -1.5125           -1.5126           -1.5115           -1.5145
     15.00              .0538            -.7543            -.7630            -.7630            -.7622            -.7642
     16.00             1.0167             .1389             .1358             .1357             .1373             .1359
     17.00             1.8156            1.0967            1.1024            1.1019            1.1056            1.1065
     18.00             2.2980            1.9578            1.9707            1.9648            1.9731            1.9992
     19.00             2.3815            2.4306            2.4220            2.3573            2.3458            2.7044
     20.00             2.0680            2.5720            2.5322            2.6608            2.4535            2.5407
     21.00             1.4411            2.1180            1.8984            1.7657            2.4351            1.6721
     22.00              .6461            1.3132            1.1161             .6471            2.8066             .7723
     23.00             -.1416             .4851             .2408             .2057            1.6608             .5701
     24.00             -.7547            -.0153            -.2633            -.2306             .2363            -.0296
     25.00            -1.0724            -.6431            -.7635            -.8133            -.6087            -.7152
```

Table 6-4 (continued)

```
 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


 TEST BAY SYSTEM WITH STORM WATER INPUT                              AT NODE 14, MODELING URBAN RUNOFF

DAY IS   2

 * * * * * * * * * * * * * * * * * * * *   T I M E   H I S T O R Y   O F   S T A G E   * * * * * * * * * * * * * * * * * * * *

                     JUNCTION   10     JUNCTION   12     JUNCTION   14     JUNCTION   15     JUNCTION   16     JUNCTION   18
      HOUR            HEAD(FEET)         HEAD(FEET)         HEAD(FEET)         HEAD(FEET)         HEAD(FEET)         HEAD(FEET)

       .00              -.7703             -.7934             -.7647             -.7403             -.7262             -.7069
      1.00             -1.1312            -1.1531            -1.1395            -1.1299            -1.1202            -1.1063
      2.00             -1.0739            -1.0836            -1.1248            -1.1669            -1.1763            -1.1868
      3.00              -.5607             -.5565             -.5275             -.5026             -.5024             -.4841
      4.00               .4119              .4528              .4270              .3976              .3981              .3748
      5.00               .5217              .6243              .6007              .6324              .6562              .6724
      6.00               .6452              .7112              .6676              .6548              .6509              .6536
      7.00               .6444              .6262              .6839              .7302              .7449              .7746
      8.00               .2521              .1704              .2446              .2744              .2868              .3051
      9.00              -.3025             -.3866             -.3105             -.2697             -.2536             -.2287
     10.00              -.9144             -.9719             -.9084             -.8667             -.8479             -.8226
     11.00             -1.5079            -1.5401            -1.4911            -1.4502            -1.4292            -1.4040
     12.00             -1.9627            -1.9728            -1.9568            -1.9347            -1.9177            -1.8996
     13.00             -2.0315            -2.0369            -2.0799            -2.1114            -2.1140            -2.1159
     14.00             -1.5151            -1.5143            -1.5262            -1.5320            -1.5366            -1.5281
     15.00              -.7646             -.7642             -.7758             -.7850             -.7881             -.7845
     16.00               .1356              .1365              .1249              .1189              .1178              .1196
     17.00              1.1051             1.1078             1.1053             1.1050             1.1052             1.1053
     18.00              1.9782             1.9986             2.0053             2.0216             2.0254             2.0353
     19.00              2.3979             2.6615             2.5699             2.5911             2.5965             2.6080
     20.00              2.2371             2.4255             2.3590             2.4131             2.4264             2.4693
     21.00              1.6524             1.5502             1.7370             1.7490             1.7590             1.7682
     22.00              1.0107              .7583             1.0399             1.0883             1.0992             1.1243
     23.00               .4257              .4353              .3285              .3854              .4015              .4329
     24.00              -.1536             -.2338             -.2346             -.2361             -.2286             -.2247
     25.00              -.7318             -.7663             -.6851             -.6395             -.6194             -.5084
```

Table 6-4 (continued)

```
 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


 TEST BAY SYSTEM WITH STORM WATER INPUT                        AT NODE 14, MODELING URBAN RUNOFF

DAY IS   2

 * * * * * * * * * * * * * * * * *  T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y * * * * * * * * * * * * * * *

                      CHANNEL  1   2  CHANNEL  3   4  CHANNEL  4   7  CHANNEL  6  11  CHANNEL 11  12  CHANNEL 11  14
       HOUR              FLOW  VEL.      FLOW  VEL.      FLOW  VEL.      FLOW  VEL.      FLOW  VEL.      FLOW  VEL.
                        (CFS) (FPS)     (CFS) (FPS)     (CFS) (FPS)     (CFS) (FPS)     (CFS) (FPS)     (CFS) (FPS)

        .00          -158604. -2.27  -424169.  -.13  -181465. -3.27  102415.   .52    33990.   .27    -5077.  -.60
       1.00           -75540. -1.08  -351673.  -.74  -187006. -2.12   85393.   .47    17969.   .16    -4336.  -.46
       2.00            94050.  1.22  -310678. -1.05  -166070. -1.40   81384.   .46     8841.   .08     -988.  -.10
       3.00           161330.  2.03  -286819. -1.02  -159632. -1.21   79326.   .44     3038.   .05      682.   .05
       4.00           103318.  1.17  -262868.  -.64  -182074. -1.50   77530.   .39     2427.   .07     -468.  -.05
       5.00            40891.   .28  -191454.   .79  -196331. -2.73   68921.   .29     6313.   .22    -2821.  -.29
       6.00            41829.   .11  -169974.  2.11  -210906. -4.18   70859.   .20    11632.   .49    -1419.  -.18
       7.00           -73218. -1.32  -237637.  2.02  -250936. -4.61   81955.   .23    22956.   .65    -3745.  -.38
       8.00          -174656. -2.50  -337280.  1.45  -257302. -4.43   95787.   .34    37270.   .64    -5686.  -.54
       9.00          -197191. -2.79  -383775.   .76  -234548. -3.89   97266.   .42    41130.   .50    -5901.  -.59
      10.00          -196759. -2.78  -355400.   .01  -215054. -2.98   83140.   .41    31949.   .32    -6072.  -.63
      11.00          -169394. -2.38  -301135.  -.76  -197185. -1.87   68304.   .38    21869.   .18    -5813.  -.60
      12.00           -99869. -1.37  -250818. -1.10  -177977. -1.19   59181.   .36    15025.   .10    -4847.  -.50
      13.00            70770.  1.03  -225852. -1.12  -145549.  -.87   58940.   .36     9801.   .06    -2062.  -.20
      14.00           193429.  2.59  -219760. -1.08  -126818.  -.73   62281.   .37     5517.   .03     2659.   .27
      15.00           245752.  3.14  -218373. -1.03  -121623.  -.67   63683.   .37     4276.   .02     1196.   .12
      16.00           283119.  3.45  -221018. -1.00  -120403.  -.63   66828.   .37     1732.   .01     4002.   .36
      17.00           266190.  3.33  -223705.  -.95  -125758.  -.64   68262.   .36      956.   .01     2527.   .21
      18.00           231994.  2.59  -216794.  -.79  -141256.  -.79   67856.   .34      270.   .01     2752.   .22
      19.00            93767.   .83  -111182.   .81  -217906. -2.36   58513.   .23     9806.   .20     -963.  -.11
      20.00          -125425. -1.84   -59089.  2.62  -369711. -5.46   65643.  -.02    29547.  1.12    -6224.  -.54
      21.00          -229509. -2.98  -433751.  1.13  -397950. -5.19  152622.   .45    80136.  1.39    -5547.  -.35
      22.00          -241665. -3.21  -846081.  -.33  -104017. -3.48  263213.  1.17   199230.  1.50    -7346.  -.51
      23.00          -187772. -2.79  -760755.  1.23  -171647. -6.09  207325.   .95   130831.   .81    -6814.  -.89
      24.00          -190329. -2.79  -585603.   .69  -543398. -6.96  119251.   .55     4755.   .20    -4882.  -.70
      25.00          -173576. -2.44  -518490.  -.73  -611022. -5.19   97015.   .49   -15617.   .05    -5331.  -.58
```

Table 6-4 (continued)

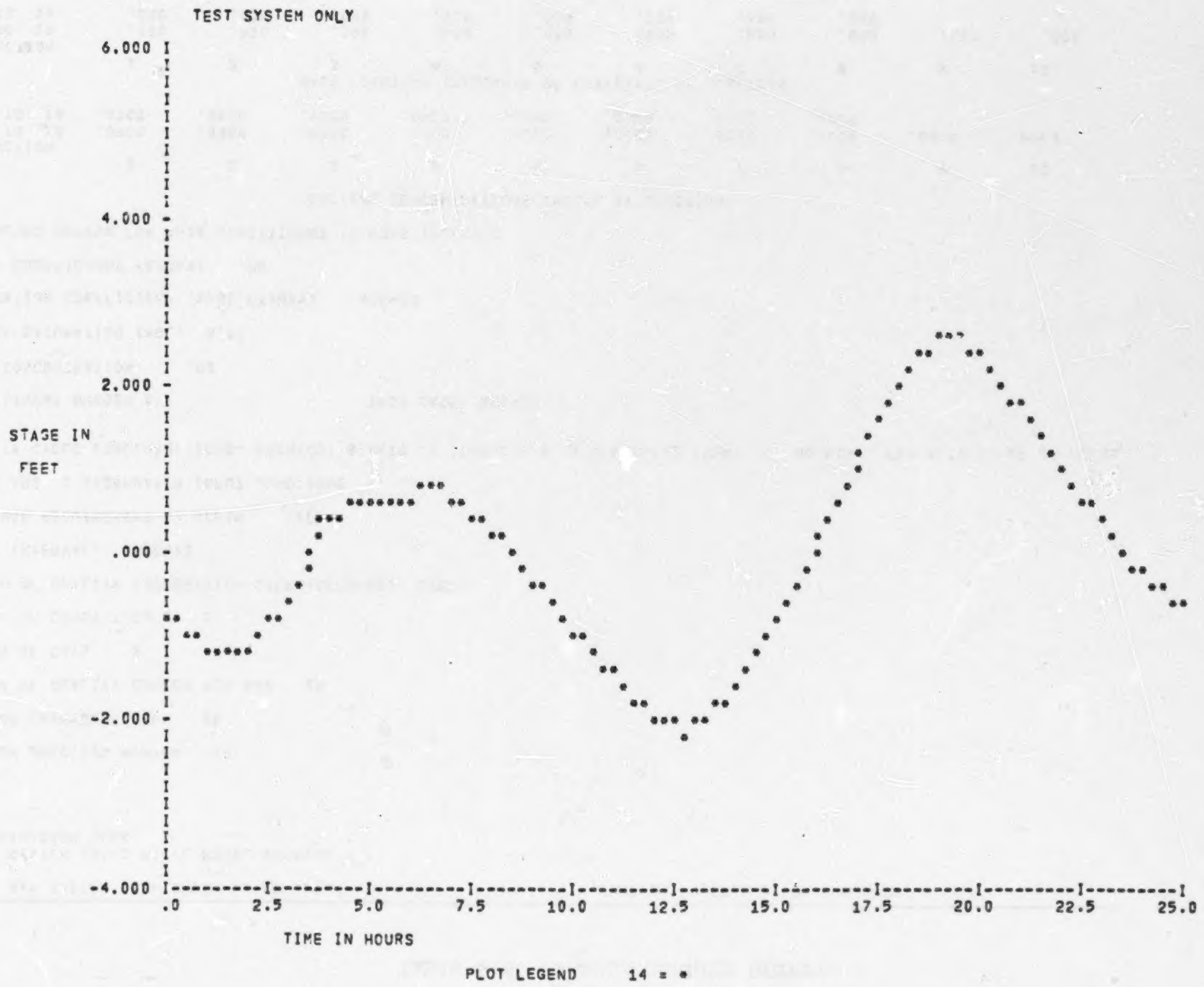


Table 6-5. SAMPLE QUALITY OUTPUT

```
TEST BAY SYSTEM WITH STORM WATER INPUT                    AT NODE 14, MODELING URBAN RUNOFF

 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


MAXIMUM JUNCTION NUMBER   18

MAXIMUM CHANNEL NUMBER   28

NUMBER OF QUALITY CYCLES PER DAY   25

NUMBER OF DAYS    2

NUMBER OF CONSTITUENTS   1

LENGTH OF QUALITY INTEGRATION STEP (SECONDS)  3600.

PRINT INTERVAL,   1 DAYS

EXCHANGE REQUIREMENT AT OCEAN    .20

THERE ARE  1 STORMWATER INPUT JUNCTIONS

QUALITY CYCLE CONCENTRATIONS, PRINTOUT STARTS IN TIME CYCLE  2 , PRINTED EVERY  5  HOUR(S), FOR A TOTAL OF 25 HOURS

CONSTITUENT NUMBER 1                      TEST CASE, BOD-DO

SINK CONCENTRATION     .00

OXYGEN SATURATION (MGL)  8.00

REAERATION COEFFICIENT (1/SQ FT/DAY)   .400-08

DECAY COEFFICIENT (1/DAY)   .20

DISSOLVED OXYGEN FOR THIS CONSTITUENT IS CONSTITUENT 2

                                  INITIAL CONCENTRATIONS (MGL), BY JUNCTION

                  1        2        3        4        5        6        7        8        9       10
 JUNCTION
 1  TO  10     .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000
11  TO  18     .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000

                                MASS LOADINGS (MILLIONS OF LBS/DAY), BY JUNCTION
                  1        2        3        4        5        6        7        8        9       10
 JUNCTION
 1 TO  10        .000     .000     .000     .000     .000     .000     .000     .000     .000     .000
11 TO  18        .000     .000     .000     .000     .000     .000     .000     .000
```

Table 6-5 (continued)

```
TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK

TEST BAY SYSTEM WITH STORM WATER INPUT                         AT NODE 14, MODELING URBAN RUNOFF

JUNCTION CONCENTRATIONS, DURING TIME CYCLE   2 ,QUALITY CYCLE   5


               CONSTITUENT NUMBER  1 TEST CASE, BOD-DO
                 1          2          3          4          5          6          7          8          9         10
   JUNCTION
  1 TO  10   .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000
 11 TO  18   .1138-02   .0000      .0000      .4486+01   .0000      .0000      .0000      .0000

               CONSTITUENT NUMBER  2 TEST CASE, BOD-DO  (DO)
                 1          2          3          4          5          6          7          8          9         10
   JUNCTION
  1 TO  10   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01 , .8000+01   .8000+01   .8000+01   .8000+01   .8000+01
 11 TO  18   .8000+01   .8000+01   .8000+01   .7976+01   .8000+01   .8000+01   .8000+01   .8000+01
          INPUT, POUNDS PER DAY, CONSTITUENT NUMBER    1 AT    5.33 HOURS FROM START

             14  .0000
          INPUT, POUNDS PER DAY, CONSTITUENT NUMBER    1 AT  277.78 HOURS FROM START

             14  .0000
 TEST SYSTEM USING FINAL MODEL VERSION
 DEMONSTRATION DECK


 TEST BAY SYSTEM WITH STORM WATER INPUT                        AT NODE 14, MODELING URBAN RUNOFF

 JUNCTION CONCENTRATIONS, DURING TIME CYCLE   2 ,QUALITY CYCLE  10


               CONSTITUENT NUMBER  1 TEST CASE, BOD-DO
                 1          2          3          4          5          6          7          8          9         10
   JUNCTION
  1 TO  10   .2203-05   .8529-05   .6994-04   .1923-03   .8262-04   .1051-04   .2342-02   .1003-03   .1626-04   .0000
 11 TO  18   .5911-01   .2658-02   .3333-04   .1188+01   .0000      .0000      .0000      .0000

               CONSTITUENT NUMBER  2 TEST CASE, BOD-DO  (DO)
                 1          2          3          4          5          6          7          8          9         10
   JUNCTION
  1 TO  10   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01
 11 TO  18   .7998+01   .8000+01   .8000+01   .7989+01   .8000+01   .8000+01   .8000+01   .8000+01
```

Table 6-5 (continued)

```
 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK


 TEST RAY SYSTEM WITH STORM WATER INPUT                              AT NODE 14, MODELING URBAN RUNOFF

JUNCTION CONCENTRATIONS, DURING TIME CYCLE   2 ,QUALITY CYCLE  15


             CONSTITUENT NUMBER  1 TEST CASE, BOD-DO
                 1          2          3          4          5          6          7          8          9         10
  JUNCTION
 1 TO  10   .1831-04   .1751-04   .7024-03   .1135-02   .8014-03   .2706-03   .5647-02   .4227-03   .3226-03   .3391-05
11 TO  18   .5286-01   .4983-02   .6069-04   .5320+00   .8880-02   .0000      .0000      .0000

             CONSTITUENT NUMBER  2 TEST CASE, BOD-DO   (DO)
                 1          2          3          4          5          6          7          8          9         10
  JUNCTION
 1 TO  10   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01
11 TO  18   .7997+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01
 TEST BAY SYSTEM WITH STORM WATER INPUT                              AT NODE 14, MODELING URBAN RUNOFF

 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK



        AVERAGE JUNCTION CONCENTRATIONS DURING TIDAL OR TIME CYCLE   2, CONSTITUENT NUMBER  1      TEST CASE, BOD-DO

                 1          2          3          4          5          6          7          8          9         10
  JUNCTION
 1  TO  10   .1367-03   .1971-03   .5739-03   .7695-03   .6055-03   .3538-03   .2799-02   .5402-03   .3872-03   .6226-05
11  TO  18   .3027-01   .3300-02   .3708-03   .8853+00   .2227-01   .0000      .6683-06   .0000

 TEST BAY SYSTEM WITH STORM WATER INPUT                              AT NODE 14, MODELING URBAN RUNOFF

 TEST SYSTEM USING FINAL MODEL VERSION
DEMONSTRATION DECK



        AVERAGE JUNCTION CONCENTRATIONS DURING TIDAL OR TIME CYCLE   2, CONSTITUENT NUMBER  2      TEST CASE, BOD-DO  (DO)

                 1          2          3          4          5          6          7          8          9         10
  JUNCTION
 1  TO  10   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01   .8000+01
11  TO  18   .7998+01   .8000+01   .8000+01   .7994+01   .7999+01   .8000+01   .8000+01   .8000+01

 RECEIVING SIMULATION COMPLETED

 ENDPROGR
```

SECTION 7

REFERENCES

BLANK PAGE

SECTION 7

REFERENCES

Runoff Block (Section 3)

1. Tucker, L.S., "Northwood Gaging Installation, Baltimore-Instrumentation and Data," Technical Memorandum No. 2, August 15, 1968, American Society of Civil Engineers, Urban Water Resources Research Program.

2. Crawford, N.H. and Linsley, R.K., "Digital Simulation in Hydrology, Stanford Watershed Model IV," Technical Report No. 39, July 1966, Department of Civil Engineering, Stanford University.

3. American Society of Civil Engineers, Manual of Engineering Practice No. 37, "Design and Construction of Sanitary and Storm Sewers," (Water Pollution Control Federation, Manual of Practice No. 9), 1960.

Transport Block (Section 4)

1. American Society of Heating and Air Conditioning Engineers, "Heating, Ventilating, Air Conditioning Guide," Annual Publication.

2. Lentz, J.J., Estimation of Design Maximum Domestic Sewage Flow Rates, Johns Hopkins University, Department of Sanitary Engineering and Water Resources, Baltimore, Maryland, 1963.

3. Geyer, J.C., and Lentz, J.J., "An Evaluation of the Problems of Sanitary Sewer System Design," Johns Hopkins University, Department of Sanitary Engineering and Water Resource, Baltimore, Maryland, 1963.

4. U.S. Department of Commerce, Environmental Data Service, Nation National Weather Records Center, Asheville, North Carolina 28801, "Local Climatological Data."

5. Portland Cement Association, "Design and Construction of Concrete Sewers," 1968, p. 13.

6. Tucker, L. Scott, "Sewage Flow Variations in Individual Homes," Technical Memorandum No. 2, 1967, American Society of Civil Engineers, Combined Sewer Separation Project, p. 8.

7. U.S. Department of Commerce, Office of Business Economics, Survey of Current Business, "Consumer Prices - All Items."

References (continued)

8. U.S. Department of Commerce, Statistical Abstracts of the United States, "Consumer Prices - All Items" and "Composite Construction Cost Index."

9. Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959.

10. Davis, C.V., Handbook of Applied Hydraulics second ed., McGraw-Hill, 1952.

11. Metcalf, L. and Eddy, H.P., American Sewerage Practice, Design of Sewers, Vol. 1, first ed., McGraw-Hill, 1914.

12. American Society of Civil Engineers, Manual of Engineering Practice No. 37, "Design and Construction of Sanitary and Storm Sewers," (Water Pollution Control Federation, Manual of Practice No. 9), 1960.

13. Henderson, F.M., Open Channel Flow, MacMillan, New York, 1970.

Appendix A

1. American Society of Heating and Air Conditioning Engineers, "Heating, Ventilating, Air Conditioning Guide," Annual Publication.

2. Hittman Associates, Inc., "A System for Calculating and Evaluating Municipal Water Requirements."

3. Linaweaver, F.P. and Geyer, J.C., "Commercial Water Use Project," Johns Hopkins University, Baltimore, Maryland.

SECTION 8

GLOSSARY AND ABBREVIATIONS

BLANK PAGE

SECTION 8

GLOSSARY

WATERSHED - The area which is drained by a river system.

DRAINAGE BASIN (STUDY AREA) - The area which contributes runoff to a stream at a given point (an individual section of a watershed).

SUBCATCHMENT - A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

SUBAREA - A subdivision of a subcatchment (generally based upon a single land use but may be identical to a subcatchment).

ABBREVIATIONS

APWA	- American Public Works Association
ASCE	- American Society of Civil Engineers
EPA	- Environmental Protection Agency
M&E	- Metcalf & Eddy, Inc.
UF	- University of Florida
USPH	- U.S. Public Health Service
WRE	- Water Resources Engineers, Inc.

BOD	- biochemical oxygen demand (5-day)
cf	- cubic feet
cfs	- cubic feet per second
COD	- chemical oxygen demand
DO	- dissolved oxygen
DWF	- dry weather flow
fpm	- feet per minute

fps - feet per second

ft - feet

gal. - gallons

gal./capita/day - gallons per capita per day

gpd - gallons per day

gph - gallons per hour

gpm - gallons per minute

gpm/sq ft - gallons per minute per square foot

gpsf - gallons per square foot

hr - hour

in. - inches

in./hr - inches per hour

JCL - job control language

lb - pounds

lb/acre/day - pounds per acre per day

lb/acre/yr - pounds per acre per year

lb/capita/day - pounds per capita per day

lb/cf - pounds per cubic foot

lb/day/cfs - pounds per day per cubic feet per second

lb/ft - pounds per foot

lb/sec - pounds per second

mgd - million gallons per day

mg/gram - milligrams per gram

mg/L - milligrams per liter

min - minutes

mm - millimeters

MPN - most probable number

ppm - parts per million

psf - pounds per square foot

psi - pounds per square inch

rpm - revolutions per minute

sec - second

sq ft - square feet

sq ft/min - square feet per minute

SS - suspended solids

tons/mo - tons per month

tons/sq mi/mo - tons per square mile per month

VSS - volatile suspended solids

yr - year

SYMBOLS

Δ	delta
α	alpha
Σ	sigma
$<$	less than
$>$	greater than
∂	partial differentiation
ρ	rho
Ψ	psi
Π	pi
θ	theta

SECTION 9

APPENDIX A

Table A-1. AVERAGE MONTHLY DEGREE-DAYS FOR CITIES IN THE UNITED STATES (BASE 65F)

State	Station	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Ala.	Anniston	0	0	17	118	438	614	614	485	381	128	25	0
	Birmingham	0	0	13	123	396	598	623	491	378	128	30	0
	Mobile	0	0	0	23	198	357	412	290	209	40	0	0
	Montgomery	0	0	0	55	267	458	483	360	265	66	0	0
Ariz.	Flagstaff	49	78	243	586	876	1135	1231	1014	949	687	465	212
	Phoenix	0	0	0	13	182	360	425	275	175	62	0	0
	Yuma	0	0	0	0	105	259	318	167	88	14	0	0
Ark.	Bentonville	1	1	38	216	516	810	879	716	519	247	86	7
	Fort Smith	0	0	9	131	435	698	775	571	418	127	24	0
	Little Rock	0	0	10	110	405	654	719	543	401	122	18	0
Calif.	Eureka	267	248	264	335	411	508	552	465	493	432	375	282
	Fresno	0	0	0	86	345	580	629	400	304	145	43	0
	Independence	0	0	28	216	512	778	799	619	477	267	120	18
	Los Angeles	0	0	17	41	140	253	328	244	212	129	68	19
	Needles	0	0	0	19	217	416	447	243	124	26	3	0
	Point Reyes	350	336	263	282	317	425	467	406	437	413	415	363
	Red Bluff	0	0	0	59	319	564	617	423	336	117	51	0
	Sacramento	0	0	17	75	321	567	614	403	317	196	85	5
	San Diego	11	7	24	52	147	255	317	247	223	151	97	43
	San Francisco	189	177	110	128	237	406	462	336	317	279	248	180
	San Jose	7	11	26	97	270	450	487	342	308	229	137	46
Colo.	Denver	0	5	103	385	711	958	1042	854	797	492	266	60
	Durango	25	37	201	535	861	1204	1271	1002	859	615	394	139
	Grand Junction	0	0	36	333	792	1132	1271	924	738	402	145	23
	Leadville	280	332	509	841	1139	1413	1470	1285	1245	990	740	434
	Pueblo	0	0	74	383	771	1051	1104	865	775	456	203	27
Conn.	Hartford	0	14	101	384	699	1082	1178	1050	871	528	201	31
	New Haven	0	18	93	363	663	1026	1113	1005	865	567	261	52
D. C.	Washington	0	0	32	231	510	831	884	770	606	314	80	0
Fla.	Apalachicola	0	0	0	17	154	304	352	263	184	33	0	0
	Jacksonville	0	0	0	11	129	276	303	226	154	14	0	0
	Key West	0	0	0	0	0	18	28	24	7	0	0	0
	Miami	0	0	0	0	5	48	57	48	15	0	0	0
	Pensacola	0	0	0	18	177	334	383	275	203	45	0	0
	Tampa	0	0	0	0	60	163	201	148	102	0	0	0
Ga.	Atlanta	0	0	8	107	387	611	632	515	392	135	24	0
	Augusta	0	0	0	59	282	494	521	412	308	62	0	0
	Macon	0	0	0	63	280	481	497	391	275	62	0	0
	Savannah	0	0	0	38	225	412	424	330	238	43	0	0
	Thomasville	0	0	2	48	208	361	359	299	178	52	5	1
Idaho	Boise	0	0	135	389	762	1054	1169	868	719	453	249	92
	Lewiston	0	0	133	406	747	961	1060	815	663	408	222	68
	Pocatello	0	0	183	487	873	1184	1333	1022	880	561	317	136
Ill.	Cairo	0	0	28	161	492	784	856	683	523	182	47	0
	Chicago	0	0	90	350	765	1147	1243	1053	868	507	229	58
	Peoria	0	11	86	339	759	1128	1240	1028	828	435	192	41
	Springfield	0	0	56	259	666	1017	1116	907	713	350	127	14
Ind.	Evansville	0	0	59	215	570	871	939	770	589	251	90	6
	Fort Wayne	0	17	107	377	759	1122	1260	1036	874	516	226	53
	Indianapolis	0	0	59	247	642	986	1051	893	725	375	140	16
	Royal Center	11	19	116	373	740	1104	1239	976	860	502	245	54
	Terre Haute	0	5	77	295	681	1023	1107	913	715	371	145	24

Table A-1 (continued)

State	Station	July	Aug.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Iowa	Charles City	17	30	151	444	912	1352	1494	1240	1001	537	256	70
	Davenport	0	7	79	320	756	1147	1262	1044	834	432	175	35
	Des Moines	0	6	89	346	777	1178	1308	1072	849	425	183	41
	Dubuque	8	28	149	444	882	1290	1414	1187	983	543	267	76
	Keokuk	1	3	71	303	680	1077	1191	1025	761	397	136	18
	Sioux City	8	17	128	405	885	1290	1423	1170	930	474	228	54
Kan.	Concordia	0	0	55	277	687	1029	1144	899	725	341	146	20
	Dodge City	0	0	40	262	669	980	1076	840	694	347	135	15
	Iola	0	1	40	236	579	930	1026	817	599	282	98	8
	Topeka	0	0	42	242	630	977	1088	851	669	295	112	13
	Wichita	0	0	32	219	597	915	1023	778	619	280	101	7
Ky.	Louisville	0	0	41	206	549	849	911	762	605	270	86	0
	Lexington	0	0	56	259	636	933	1008	854	710	368	140	15
La.	New Orleans	0	0	0	5	141	283	341	223	163	19	0	0
	Shreveport	0	0	0	53	305	490	550	386	272	61	0	0
Me.	Eastport	141	136	261	521	798	1206	1333	1201	1063	774	524	288
	Greenville	69	113	315	642	1012	1464	1625	1443	1251	842	468	194
	Portland	15	56	199	515	825	1238	1373	1218	1039	693	394	117
Md.	Baltimore	0	0	29	207	489	812	880	776	611	326	73	0
Mass.	Boston	0	7	77	315	618	998	1113	1002	849	534	236	42
	Fitchburg	12	29	144	432	774	1139	1240	1137	940	572	254	70
	Nantucket	22	34	111	372	615	924	1020	949	880	642	394	139
Mich.	Alpena	50	85	215	530	864	1218	1358	1263	1156	762	437	135
	Detroit-Willow Run	0	10	96	393	759	1125	1231	1089	915	552	244	55
	Detroit City	0	8	96	381	747	1101	1203	1972	927	558	251	60
	Escanaba	62	95	247	555	933	1321	1473	1327	1203	804	471	166
	Grand Rapids	0	20	105	394	756	1107	1215	1086	939	546	248	58
	Houghton	70	94	268	582	965	1355	1535	1421	1251	820	474	195
	Lansing	13	33	140	455	813	1175	1277	1142	986	591	287	70
	Ludington	41	55	182	472	794	1135	1271	1183	1056	698	418	153
	Marquette	69	87	236	543	933	1299	1435	1291	1181	789	477	189
	Sault Ste. Marie	109	126	298	639	1005	1398	1587	1442	1302	846	499	224
Minn.	Duluth	66	91	277	614	1092	1550	1696	1448	1252	801	487	200
	Minneapolis	8	17	157	459	960	1414	1562	1310	1057	570	259	80
	Moorhead	20	47	240	607	1105	1609	1815	1555	1225	679	327	98
	St. Paul	12	21	154	459	951	1401	1553	1305	1051	564	256	77
Miss.	Corinth	0	1	13	142	418	669	696	570	396	149	32	1
	Meridian	0	0	0	90	338	528	561	413	309	85	9	0
	Vicksburg	0	0	0	51	268	456	507	374	273	71	0	0
Mo.	Columbia	0	6	62	262	654	989	1091	876	698	326	135	14
	Hannibal	1	3	66	288	652	1037	1139	980	710	374	128	15
	Kansas City	0	0	44	240	621	970	1085	851	666	292	111	8
	St. Louis	0	0	38	202	570	893	983	792	620	270	94	7
	Springfield	0	8	61	249	615	908	1001	790	632	295	118	16
Mont.	Billings	8	20	194	497	876	1172	1305	1089	958	564	304	119
	Harve	20	38	270	564	1023	1383	1513	1291	1076	597	313	125
	Helena	51	78	359	598	969	1215	1438	1114	992	660	427	225
	Kalispell	47	83	326	639	990	1249	1386	1120	970	639	391	215
	Miles City	6	11	187	525	966	1373	1516	1257	1048	570	285	106
	Missoula	22	57	292	623	993	1283	1414	1100	939	609	365	176
Neb.	Drexel	4	6	95	405	788	1271	1353	1096	843	493	219	38
	Lincoln	0	7	79	310	741	1113	1240	1000	794	377	172	32
	North Platte	7	11	120	425	846	1172	1271	1016	887	489	243	59
	Omaha	0	5	88	331	783	1166	1302	1058	831	389	175	32
	Valentine	11	10	145	461	891	1212	1361	1100	970	543	288	83

Table A-1 (continued)

State	Station	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Nev.	Reno	27	61	165	443	744	986	1048	804	756	519	318	165
	Tonopah	0	5	96	422	723	995	1082	860	763	504	272	91
	Winnemucca	0	17	180	508	822	1085	1153	854	794	546	299	111
N.H.	Concord	11	57	192	527	849	1271	1392	1226	1029	660	316	82
N.J.	Atlantic City	0	0	29	230	507	831	905	829	729	[illegible]68	189	24
	Cape May	1	2	38	221	527	852	936	876	737	[illegible]59	188	33
	Newark	0	0	47	301	603	961	1039	932	760	450	148	11
	Sandy Hook	1	2	40	268	579	921	1016	973	833	499	206	31
	Trenton	0	0	55	285	582	930	1004	904	735	429	133	11
N.M.	Albuquerque	0	0	10	218	630	899	970	714	589	289	70	0
	Roswell	0	0	8	156	501	750	787	566	443	185	28	0
	Santa Fe	12	15	129	451	772	1071	1094	892	786	544	297	60
N.Y.	Albany	0	6	98	388	708	1113	1234	1103	905	531	202	31
	Binghamton	0	36	141	428	735	1113	1218	1100	927	570	240	48
	Buffalo	16	30	122	433	753	1116	1225	1128	992	636	315	72
	Canton	27	61	219	550	898	1368	1516	1385	1139	695	340	107
	Ithaca	17	40	156	451	770	1129	1236	1156	978	606	292	83
	New York	0	0	31	250	552	902	1001	910	747	435	130	7
	Oswego	20	39	139	430	738	1132	1249	1134	995	654	355	90
	Rochester	9	34	133	440	759	1141	1249	1148	992	615	289	54
	Syracuse	0	29	117	396	714	1113	1225	1117	955	570	247	37
N.C.	Asheville	0	0	50	262	552	769	794	678	572	285	105	5
	Charlotte	0	0	7	147	438	682	704	577	449	172	29	0
	Hatteras	0	0	0	63	244	481	527	487	394	171	25	0
	Manteo	0	0	7	113	358	595	642	594	469	249	75	7
	Raleigh	0	0	10	118	387	651	691	577	440	172	29	0
	Wilmington	0	0	0	73	288	508	533	463	347	104	7	0
N.D.	Bismarck	29	37	227	598	1098	1535	1730	1464	1187	657	355	116
	Devils Lake	47	61	276	654	1197	1558	1866	1576	1314	750	394	137
	Grand Forks	32	60	274	663	1160	1631	1895	1608	1298	718	359	123
	Williston	29	42	261	605	1101	1528	1705	1442	1194	663	360	138
Ohio	Cincinnati	0	0	42	222	567	880	942	812	645	314	108	0
	Cleveland	0	9	60	311	636	995	1101	977	846	510	223	49
	Columbus	0	0	59	299	654	983	1051	907	741	408	153	22
	Dayton	0	5	74	324	693	1032	1094	941	781	435	179	39
	Sandusky	0	0	66	327	684	1039	1122	997	853	513	217	41
	Toledo	0	12	102	387	756	1119	1197	1056	905	555	245	60
Okla.	Broken Arrow	0	0	28	169	513	805	881	646	506	212	61	5
	Oklahoma City	0	0	12	149	459	747	843	630	472	169	38	0
Ore.	Baker	25	47	255	518	852	1138	1268	972	837	591	384	200
	Medford	0	0	77	326	624	822	862	627	552	381	207	69
	Portland	13	14	85	280	534	701	791	594	515	347	199	70
	Roseburg	14	10	98	288	531	694	744	563	508	366	223	83
Pa.	Erie	0	17	76	352	672	1020	1128	1039	911	573	273	55
	Harrisburg	0	0	69	308	630	964	1051	921	750	423	128	14
	Philadelphia	0	0	33	219	516	856	933	837	667	369	93	0
	Pittsburgh	0	0	56	298	612	924	992	879	735	402	137	13
	Reading	0	5	57	285	588	936	1017	902	725	411	123	11
	Scranton	0	18	115	389	693	1057	1141	1028	849	516	196	35
R.I.	Block Island	6	21	88	330	591	927	1026	955	865	603	335	96
	Narragansett Pier	1	26	121	366	691	1012	1113	1074	916	622	342	113
	Providence	0	7	68	330	624	986	1076	972	809	507	197	31
S.C.	Charleston	0	0	0	34	214	410	445	363	260	43	0	0
	Columbia	0	0	0	76	308	524	538	443	318	77	0	0
	Due West	0	0	9	142	393	594	651	491	411	158	39	2
	Greenville	0	0	10	131	411	648	673	552	442	161	32	0

Table A-1 (continued)

State	Station	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
S.D.	Huron	10	16	149	472	975	1407	1597	1327	1032	558	279	80
	Pierre	4	11	136	438	887	1317	1460	1253	971	516	233	52
	Rapid City	32	24	193	500	891	1218	1361	1151	1045	615	357	148
Tenn.	Chattanooga	0	0	24	169	477	710	725	588	467	179	45	0
	Knoxville	0	0	33	179	498	744	760	630	500	196	50	0
	Memphis	0	0	13	98	392	639	716	574	423	131	20	0
	Nashville	0	0	22	154	471	725	778	636	498	186	43	0
Texas	Abilene	0	0	5	98	350	595	673	479	344	113	0	0
	Amarillo	0	0	37	240	594	859	921	711	586	298	99	0
	Austin	0	0	0	30	214	402	484	322	211	50	0	0
	Brownsville	0	0	0	0	59	159	219	106	74	0	0	0
	Corpus Christi	0	0	0	0	113	252	330	192	118	6	0	0
	Dallas	0	0	0	53	299	518	607	432	288	75	0	0
	Del Rio	0	0	0	26	188	371	419	235	147	21	0	0
	El Paso	0	0	0	70	390	626	670	445	330	110	0	0
	Fort Worth	0	0	0	58	299	533	622	446	308	90	5	0
	Galveston	0	0	0	0	131	271	356	247	176	30	0	0
	Houston	0	0	0	0	162	303	378	240	166	27	0	0
	Palestine	0	0	0	45	260	440	531	368	265	71	0	0
	Port Arthur	0	0	0	8	170	315	381	258	181	27	0	0
	San Antonio	0	0	0	25	201	374	462	293	190	34	0	0
	Taylor	0	0	2	56	234	462	494	375	214	64	8	0
Utah	Modena	6	11	156	499	832	1142	1190	944	816	567	338	97
	Salt Lake City	0	0	61	330	714	995	1119	857	701	414	208	64
Vt.	Burlington	19	47	172	521	858	1308	1460	1313	1107	681	307	72
	Northfield	62	112	283	602	947	1389	1524	1384	1176	754	405	166
Va.	Cape Henry	0	0	0	120	366	648	698	636	512	267	60	0
	Lynchburg	0	0	49	236	531	809	846	722	584	289	82	5
	Norfolk	0	0	5	118	354	636	679	602	464	220	41	0
	Richmond	0	0	31	181	456	750	787	695	529	254	57	0
	Wytheville	7	13	82	352	662	916	945	836	677	410	168	35
Wash.	North Head L.H. Reservation	239	205	234	341	486	636	704	585	598	492	406	285
	Seattle	49	45	134	329	540	679	753	602	558	396	246	107
	Spokane	17	28	205	508	879	1113	1243	988	834	561	330	146
	Tacoma	66	62	177	375	579	719	797	636	595	435	282	143
	Tatoosh Island	295	288	315	406	528	648	713	610	629	525	437	330
	Walla Walla	0	0	93	308	675	890	1023	748	564	338	171	38
	Yakima	0	7	150	446	807	1066	1181	862	660	408	205	53
W.Va.	Elkins	9	31	122	412	726	995	1017	910	797	477	224	53
	Parkersburg	0	0	56	272	600	896	949	826	672	347	119	13
Wis.	Green Bay	32	58	183	515	945	1392	1516	1336	1132	696	347	107
	La Crosse	11	20	152	447	921	1380	1528	1280	1035	552	250	74
	Madison	10	30	137	419	864	1287	1417	1207	1011	573	266	79
	Milwaukee	11	24	112	397	795	1184	1302	1117	961	606	335	100
	Wausau	26	58	216	568	982	1427	1594	1381	1147	680	315	100
Wyo.	Cheyenne	33	39	241	577	897	1125	1225	1044	1029	717	315	100
	Lander	7	23	244	632	1050	1383	1494	1179	1045	687	396	163
	Yellowstone Park	125	173	424	759	1079	1386	1464	1252	1165	841	603	334

Source: American Society of Heating and Air Conditioning Engineers, "Heating, Ventilating, Air Conditioning Guide," Annual Publication (Ref. 1).

Table A-2. GUIDE FOR ESTABLISHING WATER USAGE IN COMMERCIAL SUBAREAS

Commercial category	Parameter	Coefficients, mean annual water use, gpd/unit of parameter
Barber Shops	Barber Chair	97.5
Beauty Shops	Station	532.0
Bus-Rail Depots	Sq ft	5.0
Car Washes	Inside Sq ft	4.78
Churches	Member	0.14
Golf-Swim Clubs	Member	33.3-100.0
Bowling Alleys	Alley	200.0
Colleges Resid.	Student	179.0
Hospitals	Bed	150.0-559.0
Hotels	Sq ft	0.256
Laundromats	Sq ft	6.39
Laundries	Sq ft	0.64
Medical Offices	Sq ft	0.62
Motels	Sq ft unit	0.33
Drive-In Movies	Car Stall	8.0
Nursing Homes	Bed	75.0-209.0
New Office Bldgs.	Sq ft	0.16
Old Office Bldgs.	Sq ft	0.27
Jails and Prisons	Occupant Person	10.0-15.0 200.0
Restaurants	Seat	10.0-90.0
Drive-In Restaurants	Car Stalls	109.0

Table A-2 (continued)

Commercial category	Parameter	Coefficients, mean annual water use, gpd/unit of parameter
Night Clubs	Person Served	2.0
Retail Space	Sale Sq ft	0.16
Schools, Elementary	Student	6.0-15.0
Schools, High	Student	10.0-19.9
YMCA-YWCA	Person	50.0
Service Stations	Inside Sq ft	0.49
Theaters	Employee Seat	30.0 5.0
Apartments	Dwelling Unit	50.0-195.0
Shopping Centers	Sq ft	0.20

Sources: Hittman Associates, Inc., "A System for Calculating and Evaluating Municipal Water Requirements" (Ref. 2); and F. P. Linaweaver and J. C. Geyer, "Commercial Water Use Project," Johns Hopkins University, Baltimore, Maryland.

Table A-3. GUIDE FOR ESTABLISHING WATER USAGE IN INDUSTRIAL SUBAREAS

Industrial category	Standard Industrial Classification Number	Mean Annual Usage Coefficients gpd/employee
Meat Products	201	903.890
Dairies	202	791.350
Can, Frozen Food	203	784.739
Grain Mills	204	488.249
Bakery Products	205	220.608
Sugar	206	1433.611
Candy	207	244.306
Beverages	208	1144.868
Miscellaneous Foods	209	1077.360
Cigarettes	211	193.613
Weaving, Cotton	221	171.434
Weaving, Synthetics	222	344.259
Weaving, Wool	223	464.439
Knitting Mills	225	273.429
Textile Finish	226	810.741
Floor Covering	227	297.392
Yarn-Thread Mill	228	63.558
Miscellaneous Textile	229	346.976
Whl. Apparel Industry	230	20.000
Saw-Planning Mill	242	223.822
Millwork	243	316.420
Wood Containers	244	238.000
Miscellaneous Wood	249	144.745
Home Furniture	251	122.178
Furniture Fixture	259	122.178
Pulp Mills	261	13494.110
Paper Mills	262	2433.856
Paperboard Mills	263	2464.478
Paper Products	264	435.790
Paperboard Boxes	265	154.804
Building Paper Mills	266	583.355
Whl. Print Industry	270	15.000
Basic Chemicals	281	2744.401
Fibers, Plastic	282	864.892
Drugs	283	457.356
Soap-Toilet Goods	284	672.043
Paint Allied Products	285	845.725
Gum-Wood Chemicals	286	332.895
Agricultural Chem.	287	449.836
Miscellaneous Chemicals	289	984.415

Table A-3 (continued)

Industrial category	Standard Industrial Classification Number	Mean Annual Usage Coefficients gpd/employee
Petroleum Refining	291	3141.100
Paving-Roofing	295	829.592
Tires, Tubes	301	375.211
Rubber Footware	302	82.592
Reclaimed Rubber	303	1031.523
Rubber Products	306	371.956
Plastic Products	307	527.784
Leather Tanning	311	899.500
Flat Glass	321	590.140
Pressed, Blown Glassware	322	340.753
Products of Purchased Glass	323	872.246
Cement, Hydraulic	324	279.469
Structural Clay	325	698.197
Pottery Products	326	326.975
Cement, Plaster	327	353.787
Cut Stone Products	328	534.789
Non-Metallic Mineral	329	439.561
Steel-Rolling	331	494.356
Iron, Steel Foundries	332	411.052
Prime Non-Ferrous	333	716.626
Secondary Non-Ferrous	334	1016.596
Non-Ferrous Rolling	335	675.475
Non-Ferrous Foundries	336	969.586
Prime Metal Industries	339	498.331
Metal Cans	341	162.547
Cutlery, Hardware	342	459.300
Plumbing, Heating	343	411.576
Structure, Metal	344	319.875
Screw Machine	345	433.193
Metal Stamping	346	463.209
Metal Service	347	1806.611
Fabricated Wire	348	343.367
Fabricated Metal	349	271.186
Engines, Turbines	351	197.418
Farm Machinery	352	320.704
Construction Equipment	353	218.365

Table A-3 (continued)

Industrial category	Standard Industrial Classification Number	Mean Annual Usage Coefficients gpd/employee
Metalwork, Machinery	354	196.255
Special Industry Machinery	355	290.494
General Industrial Machinery	356	246.689
Office Machines	357	138.025
Service Industrial Machine	358	334.203
Miscellaneous Machines	359	238.839
Electric Distribution Products	361	272.001
Electric Industrial Apparatus	362	336.016
Home Appliances	363	411.914
Light-Wiring Fixtures	364	369.592
Radio TV Receiving	365	235.763
Communication Equipment	366	86.270
Electronic Comp.	367	203.289
Electric Product	369	393.272
Motor Vehicles	371	318.233
Aircraft and Parts	372	154.769
Ship and Boat Building	373	166.074
Railroad Equipment	374	238.798
Motorcycle, Bike	375	414.858
Scientific Instruments	381	181.007
Mechanical Measure	383	237.021
Medical Instrument	384	506.325
Photo Equipment	386	120.253
Watches, Clocks	387	164.815
Jewelry, Silver	391	306.491
Toys, Sport Goods	394	213.907
Costume Jewelry	396	423.124
Miscellaneous Manufacturing	398	258.270
Miscellaneous Manufacturing	399	258.270

Source: Hittman Associates, Inc., "A System for Calculating and Evaluating Municipal Water Requirements" (Ref. 2).

1 *Accession Number*

2 *Subject Field & Group*
013B

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 *Organization*
Metcalf & Eddy, Inc., Palo Alto, California
Florida University, Gainesville, Dept. of Environmental Engineering
Water Resources Engineers, Inc., Walnut Creek, California

6 *Title*
STORM WATER MANAGEMENT MODEL

10 *Author(s)*
Lager, John A.,
Pyatt, Edwin E., and
Shubinski, Robert P.

16 *Project Designation*
EPA Contract Nos. 14-12-501, 502, 503

21 *Note*
Set of four volumes: Volume I - Final Report, Volume II - Verification and Testing, Volume III - User's Manual, Volume IV - Program Listing

22 *Citation*

23 *Descriptors (Starred First)*
Water Quality Control*, Computer Model*, Storm Water*, Simulation Analysis, Rainfall-Runoff Relationships, Sewerage, Storage, Waste Water Treatment, Cost Benefit Analysis

25 *Identifiers (Starred First)*
Combined Sewer Overflows*, Urban Runoff

27 *Abstract*

A comprehensive mathematical model, capable of representing urban storm water runoff, has been developed to assist administrators and engineers in the planning, evaluation, and management of overflow abatement alternatives. Hydrographs and pollutographs (time varying quality concentrations or mass values) were generated for real storm events and systems from points of origin in real time sequence to points of disposal (including travel in receiving waters) with user options for intermediate storage and/or treatment facilities. Both combined and separate sewerage systems may be evaluated. Internal cost routines and receiving water quality output assisted in direct cost-benefit analysis of alternate programs of water quality enhancement. Demonstration and verification runs on selected catchments, varying in size from 180 to 5,400 acres, in four U.S. cities (approximately 20 storm events, total) were used to test and debug the model. The amount of pollutants released varied significantly with the real time occurrence, runoff intensity duration, pre-storm history, land use, and maintenance. Storage-treatment combinations offered best cost-effectiveness ratios. A user's manual and complete program listing were prepared.

Abstractor John A. Lager

Institution Project Manager, Metcalf & Eddy, Inc.

WR:102 (REV. JULY 1969)
WRSIC

SEND TO: WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

★ GPO: 1969-359-339

Continued from inside front cover....

11022 --- 08/67	Phase I - Feasibility of a Periodic Flushing System for Combined Sewer Cleaning
11023 --- 09/67	Demonstrate Feasibility of the Use of Ultrasonic Filtration in Treating the Overflows from Combined and/or Storm Sewers
11020 --- 12/67	Problems of Combined Sewer Facilities and Overflows, 1967 (WP-20-11)
11023 --- 05/68	Feasibility of a Stabilization-Retention Basin in Lake Erie at Cleveland, Ohio
11031 --- 08/68	The Beneficial Use of Storm Water
11030 DNS 01/69	Water Pollution Aspects of Urban Runoff, (WP-20-15)
11020 DIH 06/69	Improved Sealants for Infiltration Control, (WP-20-18)
11020 DES 06/69	Selected Urban Storm Water Runoff Abstracts, (WP-20-21)
11020 --- 06/69	Sewer Infiltration Reduction by Zone Pumping, (DAST-9)
11020 EXV 07/69	Strainer/Filter Treatment of Combined Sewer Overflows, (WP-20-16)
11020 DIG 08/69	Polymers for Sewer Flow Control, (WP-20-22)
11023 DPI 08/69	Rapid-Flow Filter for Sewer Overflows
11020 DGZ 10/69	Design of a Combined Sewer Fluidic Regulator, (DAST-13)
11020 EKO 10/69	Combined Sewer Separation Using Pressure Sewers, (ORD-4)
11020 --- 10/69	Crazed Resin Filtration of Combined Sewer Overflows, (DAST-4)
11024 FKN 11/69	Stream Pollution and Abatement from Combined Sewer Overflows - Bucyrus, Ohio, (DAST-32)
11020 DWF 12/69	Control of Pollution by Underwater Storage
11000 --- 01/70	Storm and Combined Sewer Demonstration Projects - January 1970
11020 FKI 01/70	Dissolved Air Flotation Treatment of Combined Sewer Overflows, (WP-20-17)
11024 DOK 02/70	Proposed Combined Sewer Control by Electrode Potential
11023 FDD 03/70	Rotary Vibratory Fine Screening of Combined Sewer Overflows, (DAST-5)
11024 DMS 05/70	Engineering Investigation of Sewer Overflow Problem - Roanoke, Virginia
11023 EVO 06/70	Microstraining and Disinfection of Combined Sewer Overflows
11024 --- 06/70	Combined Sewer Overflow Abatement Technology
11034 FKL 07/70	Storm Water Pollution from Urban Land Activity
11022 DMU 07/70	Combined Sewer Regulator Overflow Facilities
11024 EJC 07/70	Selected Urban Storm Water Abstracts, July 1968 - June 1970
11020 --- 08/70	Combined Sewer Overflow Seminar Papers
11022 DMU 08/70	Combined Sewer Regulation and Management - A Manual of Practice
11023 --- 08/70	Retention Basin Control of Combined Sewer Overflows
11023 FIX 08/70	Conceptual Engineering Report - Kingman Lake Project
11024 EXF 08/70	Combined Sewer Overflow Abatement Alternatives - Washington, D.C.